THE
GEOLOGICAL MAGAZINE
VOLUME LXIV.

No. X.—OCTOBER, 1927.

ORIGINAL ARTICLES.

On the Present Climatic Equivalence of British Raised Beach Mollusca.

By D. Baden-Powell, M.A., B.Sc., F.R.G.S., F.G.S.

THE object of this preliminary note is to inquire how far the marine mollusca can be used in correlating the Quaternary marine deposits in Britain.

A connexion between the existing fauna and that of the Raised Beaches has long been recognized. For instance, the " Clyde Beds " around Glasgow and on the West Coast of Scotland are now generally admitted to contain an " arctic " fauna, as was first pointed out by James Smith of Jordanhill.[1]

Of the Raised Beach shells found at Portland, Dr. Jeffreys has written : " All the species (that is, from Portland) inhabit the British coasts from Shetland to Yorkshire." [2]

Godwin-Austen has described the warm episode represented in the Quaternary sequence at Selsey Bill as that which would now be found " 12 degrees further south " (than the English Channel).[3]

In the Torquay Museum there is a very interesting tablet bearing specimens of *Trophon clathratus* var. *truncatus* and *Bela turricula*, and the following note in the writing of A. R. Hunt, " Northern forms not now found on the south coast of Devon."

Sequence of Climatic Changes.—If the sequence of the climatic changes that have characterized the Quaternary epoch in this country could be determined by a study of the Raised Beach shells, the correlation of the different Raised Beaches should be greatly facilitated. In order to do this, some means must be devised for measuring as accurately as possible the climate represented by the Raised Beach shells in each individual example.

Measurement of Climatic Equivalence.—Every association of shells found fossil in any Raised Beach should have some area in which the same association could be found at the present day, and this might be termed the " climatic equivalent area " of the beach. If such an area includes the Raised Beach locality, there is obviously little or no difference between the Raised Beach climate and that of the present day at the same place. If the area lies to the north or south of the Raised Beach locality, it is obvious that the Raised Beach climate must have been respectively colder or warmer than at present.

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[1] James Smith, *Researches in New Pliocene and Post-Tertiary Geology*, Glasgow, 1862.

[2] Gwyn Jeffreys, *Quart. Journ. Geol. Soc.*, xxxi, 1875, p. 52.

[3] R. A. C. Godwin-Austen, ibid., xiii, 1857, p. 40.

It is true to a certain extent to say that the distance between the Raised Beach locality and its area of climatic equivalence represents the degree of difference between the Raised Beach climate and that of the present day.

Height and Climatic Equivalence.—I have attempted to measure the climatic equivalent of a number of Raised Beaches and associated marine clays, and have found that there exists a direct connexion between the height of the beds above sea-level and their climatic equivalence.

By the height of a Raised Beach should be understood the difference between the height of high-water mark in Raised Beach times and present Ordnance Datum. This ensures that the heights of Raised Beaches can be referred to some common datum line. Much confusion regarding the heights of Raised Beaches has been caused in the past by measurement being made at various chance places down the Raised Beach platform, which has, just as a modern beach, a seaward gradient.

In examples where the Raised Beach deposits have been denuded away, or partially disconnected from the contemporaneous Laminarian deposits, the age must be determined by finding its climatic equivalent, since the height of the Raised Beach high-water mark can no longer be found. This means that examples are of double importance in which both the height and the climatic equivalent can be determined.

Practical Application of Climatic Equivalence.—The actual cases in which climatic equivalent has been determined include some sixty sections in the Quaternary marine deposits of England and Scotland. For the altitudes of the deposits and the identification of the shells I have depended largely upon the work of former geologists. From these I select a few of the more typical examples, including some of those which I have had the best opportunities of verifying.

The Irish deposits have been omitted from the present paper because I propose to deal with them later on.

The Portland Bill Raised Beach is taken as an example showing the method used in all the others.[1]

All the Raised Beach shells from Portland Bill are found between the heights of 25 feet and 18 feet O.D., and three of them are chosen, whose present geographical distribution is limited and well known. The warmest of these three, *Ocinebra erinacea*, is found fossil at

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[1] "Geology of the Isle of Purbeck and Weymouth," *Mem. Geol. Surv.*, 1898, pp. 201–3.

Portland with the two colder forms, *Eumargarita helicina* and *Acmaea testudinalis*, and the area in which these three forms can now be found together at present on the coasts of Britain is bounded on the north by Tiree, Mull, and the Firth of Forth, and on the south by Lancashire and the Wash. Therefore between these two limits is the area of climatic equivalence for the Portland Bill Raised Beach.

The nomenclature of the present paper is that of the list of British Mollusca (Marine) compiled by a Committee of the Conchological Society (2nd ed.) in 1902.

The Kinness Burn Clay [1] is an estuarine deposit at about 20 feet O.D., and by a similar method, taking *Scrobicularia plana* as the northern limit of the area and *Macoma calcarea* as the southern, the climatic equivalent is between Bergen and the coast of Denmark.

When Portland and the Kinness Burn are compared, it is apparent that each of these two localities, which is approximately at the same height O.D., is also equally far south of its respective area of climatic equivalence. That is to say, that at the time of the Raised Beach the climate of the Kinness Burn differed from the present climate there by the same amount as the Raised Beach climate at Portland differed from the present climate there.

The shells from the Raised Beach near Barnstaple, which have been traced up to 60 feet O.D.,[2] indicate a warmer climate than at present, the shell indicating the northern limit of the area being *Cardium papillosum*, *Buccinum undatum* indicating the southern limit, the climatic equivalent being between the south of Cornwall and Les Landes in France.

A Scottish example of this warm fauna is found in the Kincraig Clay,[3] near Elie, in Fife. The chief shells used are *Syndosmia tenuis*, *Ondina warreni*, and *Odostomia plicata* for the northern limit, and *Crenella decussata* and *Eumargarita helicina* for the southern, the area lying between Lancashire, Yorkshire, Cheshire, and the Wash.

The "Clyde Beds" possess a colder fauna than that of Portland or the Kinness Burn, but unfortunately no examples of this deposit are known south of the Scottish Borders, so that the same shifting of the climatic equivalent area cannot be seen.

A typical example of this bed can be seen in the marine clay found at Wood Haven, in Fife, contemporaneous with the local 100 feet Raised Beach,[4] but several other Scottish examples would have done equally well. The northern limit of the area is defined by *Cyprina islandica*, and the southern by *Modiolaria discors* var. *laevigata*, *Palliolum grønlandicus*, and *Thracia myopsis*, which are now found together in that part of Norway north of the Arctic Circle.

Climatic Sequence.—It can be seen, then, that these deposits represent three distinct climates :—

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[1] "Geology of East Fife," *Mem. Geol. Surv.*, 1902, p. 304.

[2] Sedgwick and Murchison, *Quart. Journ. Geol. Soc.*, vol. ii, 1836, p. 442.

[3] "Geology of East Fife," *Mem. Geol. Surv.*, 1902, p. 303.

[4] "Geology of East Fife," *Mem. Geol. Surv.*, p. 302.

The 25 feet Beach being colder than at present; the 50 feet Raised Beach warmer; the 100 feet the coldest of all three.

It is interesting to note that this is true of the Raised Beaches of Scotland as well as of those on even the south coast of England. Each of the three Raised Beaches, therefore, possesses a characteristic climate, and although it is sometimes difficult to be certain of the height, it can be stated as a definite rule that *a certain value for climatic equivalent corresponds to a certain height of the Raised Beach.*

General Results of this Inquiry.—Of those examples which I have put to the test, I have not yet found any exceptions to the above rule.

During the course of my field work I have been able to prove to my satisfaction the geological age of the following deposits: 25 feet age: The Raised Beaches at Hope's Nose, Thatcher Stone, and Churston Cove in Tor Bay; the Raised Beach at Portland Bill; the March Gravel and the Kinness Burn Clay. From what I have seen of the shells from the Nar Valley Clay these exhibit the same 25 feet climate as the March Gravels.

In the district of Gower, in South Wales, I found both the 25 feet and the 50 feet Raised Beaches to be present, and most of the well-known caves there appear to be of either 25 feet or 50 feet age, according to the height of the basal deposits at their mouths.

To these results I must add the 50 feet Raised Beach near Barnstaple, and an unfossiliferous beach at 50 feet on Portland.

It is probable that the Goodwood Sand and the Ruffins Copse Sand in the Isle of Wight are of 100 feet age, but the fauna known from these deposits is at present very meagre.

Stratigraphical Results.—The three Raised Beaches with which I am dealing only represent what may be called "late-glacial" and "post-glacial" time, but there are other deposits on which I hope to work later, such as the Clava, Kintyre, and Butt of Lewis deposits in Scotland, and the Moel Tryfaen, Macclesfield, Kirmington, and Kelsey Hill deposits in England.

Most of these deposits are pre-100 feet, with the possible exception of the last two. The 100 feet and 50 feet beds represent episodes during the general retreat of the ice, and not marine beds deposited after its disappearance.[1] That there was some re-advance of the ice between 50 feet and 25 feet times is suggested by a study of the relation of the 50 feet Beach to the Boulder Clay, both in Scotland[2] and in Wales.[3]

The 25 feet deposits are probably more strictly post-glacial,[4] though in Scotland this Raised Beach was probably contemporaneous with the Corrie glacier stage of retreat,[5] a fact which is confirmed by

[1] "Geology of Strath Oykell," *Mem. Geol. Surv.*, 1926, p. 10.

[2] L. Hinxman, *Trans. Geol. Soc. Edin.* vi, 1893, p. 249.

[3] Tiddeman, *Brit. Ass. Report*, 1900, p. 761.

[4] "Tertiary and Post-Tertiary Geology of Mull, etc.," *Mem. Geol. Surv.*, 1924, p. 412.

[5] L. Hinxman, ibid., pp. 250–1.

the marine climate of the time. This same author suggests a possible re-advance of the valley glaciers after 25 feet times. In the light of these possibilities, no surprise need be felt that the Raised Beaches of the south of England are so often overlaid by Coombe Rock and Head.

Faunal Results.—Apart from using the climatic equivalence of the mollusca for stratigraphical purposes, one or two facts of purely faunal interest have come to light. The most important of these is that, at least since 100 feet times, no very great changes have taken place in the relative distribution of the marine mollusca.

In 25 feet times the northern limit of such forms as *Ocinebra erinacea*, *Adeorbis subcarinata*, and *Phasianella pulla* was probably even south of the present Wash, and the southern limit of such shells as *Macoma calcarea*, *Chlamys islandica*, *Bela pyramidalis*, and *Astarte borealis* was probably at least as far south as the Wash.

As a matter of fact, the abruptly cold nature of the March Gravel-Nar Valley fauna as compared with the relative warmth of the Tor Bay-Portland fauna is very suggestive of an actual barrier in 25 feet times, presumably joining south-east England to the Continent. For instance, *Astarte borealis* and *Macoma calcarea* are found fossil in Fenland, but not in the Tor Bay-Portland area; whilst *Ocinebra erinacea* is found in this last area, but not in Fenland. This is what should be expected if such a barrier existed.

The famous Selsey Mud Deposit at the point of Selsey Bill, Heron-Allen's "Verrucosa Clay",[1] possesses many forms not now found as far north as the English Channel, and is probably of 50 feet age.

The 100 feet fauna is that of northern Iceland and Finmark rather than that of East Greenland or Spitsbergen, and is, therefore, not severely Arctic. It would be exceptionally interesting to find the fauna of this deposit further south, and, as has been stated above, the most likely localities for such a find in the south of England would be in the Isle of Wight or in south-west Sussex.

It is quite possible that some other branch of marine life, such as the Foraminifera, might be used as well as the mollusca, but they seem more prone to derivability.

Tectonic Results.—No obvious warping, faulting, or folding appears to have occurred since 100 feet times. The level of the 100 feet Beach remains constant throughout Scotland according to the measurements of the Survey.

I have found the 50 feet Raised Beach at Gower, Barnstaple, and Portland; also the 25 feet Raised Beach at Gower, Newquay, Churston Cove, Thatcher Stone, Hope's Nose, Portland, and the March Gravel, to correspond exactly with these respective Raised Beaches in Scotland in their heights, quite apart from faunal considerations.

That all the Raised Beaches in the south of England are preglacial or early-glacial, as has been urged by some geologists, quite irrespective of their fauna or altitudes, does not seem to accord with the facts of faunal distribution.

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[1] *Selsey Bill, Historic and Prehistoric*, Edward Heron-Allen, 1911, p. 63.

In conclusion, I should like to express my thanks to Professor Sollas for kindly helping me to prepare this paper; to Professor Marr for much valuable help; to Mr. G. C. Robson for suggestions concerning molluscan distribution and nomenclature; and to Mr. D. Innes and Mr. S. R. Kirk for kindly providing me with specimens from the Kinness Burn Clay for examination.

A New Genus of Tabulate Corals from New South Wales.

By O. A. Jones, M.Sc. (Research Student, Emmanuel College, Cambridge).

(PLATE XII.)

THE peculiar coral to be described below was collected by Mr. R. S. Allan, of New Zealand, at Yass, New South Wales. It has a superficial resemblance to *Favosites* but close examination shows it to be imperforate and to belong to the Chaetetidae. It shows so many characters of interest that it seems to merit a full description.

Hattonia[1] gen. nov.

Corallum compound, massive. Corallites prismatic, polygonal, firmly amalgamated. Septa and mural pores absent. One to three or more tabulae occurring in groups which are regularly spaced and on the same level in contiguous corallites. Reproduction by intramural gemmation.

Hattonia etheridgei sp. nov. (Plate XII.)

Corallites small, hexagonal or pentagonal, equal or sub-equal, diameter one millimetre. Walls unthickened. Groups of tabulae (one to three, usually two, in a group), about 2·5 millimetres apart; occasional tabulae between the groups. Tabulae horizontal or oblique, complete or partial (" vesicular " of Edwards and Haime), sometimes appearing to run almost vertically from one tabula to another.

REMARKS.

This falling of the tabulae into groups is probably a manifestation of a trend which followed to its logical end would terminate in the complete absence of tabulae and the occurrence of simple tubes. The partial nature of many of the tabulae and occurrence of occasional tabulae between the groups supports this conclusion. That the *astraeoid* trend of Lang (*Proc. Geol. Assoc.*, 1923, pp. 122–3) is well advanced is shown by the predominant hexagonal form of the corallites, resulting from the compression into the compound form, "*cerioid*" stage of Lang (loc. cit., fig. 15, 4).

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[1] From the locality Hatton's Corner.

The placing of the genus in its correct family naturally hinges upon the presence or absence of mural pores. A minute examination has failed to reveal any trace of mural pores either in sections or hand specimens. That this absence is due to the nature of preservation seems to be debarred by the fact that almost all specimens of *Favosites* from the same localities and similarly preserved, show the mural pores exceptionally clearly. The absence of mural pores in any one section proves nothing, but when no trace is found in the number of sections cut in this case (five), their absence is surely definite.

Hence the general characters, the absence of septa and the imperforate condition of this coral indicate its close relationship to the Chaetetidae and its separation from the Favositidae.

In this family are placed *Chaetetes, Dania, Beaumontia, Tetradium,* and *Litophyllum*: of these *Tetradium* need not be considered since it possesses pseudo-septa in the form of folds in the walls. From *Chaetetes, Hattonia* differs in having partial or incomplete tabulae and no trace of any inflection of the wall—"septal tooth," indicating fission.

With the genus *Dania* Milne Edwards and Haime (*Comp. rend. de l'Acad. des Sc.*, t. xxix, p. 261, 1849) it agrees in having tabulae at the same level in contiguous corallites but differs in that the tabulae of *Dania* are complete and are not in groups. The validity of *Dania* as a distinct genus has been discussed by R. Etheridge, jun. (*Rec. G.S.N.S.W.*, vol. vi, pt. 3, p. 180).

The inclusion of *Beaumontia* Milne Edwards and Haime (*Pol. Foss. Terr. Pal.*, p. 276, 1851) in the Chaetetidae has been disputed by Lindström (*Ann. Mag. Nat. Hist.*, ser. IV, vol. xviii, p. 16) who suspected the presence of mural pores, and by Nicholson (*Tab. Corals of the Pal. Period*, p. 329) on its general resemblance to *Michelinia*. Etheridge, jun. (loc. cit., p. 179), however, retains it in the Chaetetidae. *Beaumontia* has solely "vesicular" tabulae nor are they in groups. Moreover, the walls do not seem to be as closely amalgamated as in *Hattonia* since on fracture they display the outside of the corallites, not the interior as in *Hattonia*. *Litophyllum* Eth. fil. (loc. cit., pp. 178–81, pls. xviii, fig. 7; xxxvi; xxxvii, fig. 1) differs from *Hattonia* in that the corallites tend to lose their polygonal form and to become rounded, in that the walls are somewhat thickened, and in that the tabulae are complete and not in groups nor at the same level in contiguous corallites.

Of the genera discussed above *Hattonia* seems to be most closely allied to *Dania* and to be intermediate between *Dania* and *Beaumontia*, but it differs markedly from all of them in the conspicuous grouping of the tabulae. Indeed, this is the most characteristic feature of the genus and it gives a peculiar external appearance to the corallum.

The writer has in his possession four specimens of this remarkable coral all showing its unusual characters in a marked degree.

Localities and Horizon.—Barrandella shales, Hatton's Corner, Yass (type locality); Limestone Creek, Yass; Derrengullen Creek, Yass. All Upper Silurian. The genotype is preserved in the University of Queensland Geological Museum.

The writer wishes to thank Dr. G. L. Elles for reading the manuscript and passing many useful criticisms.

EXPLANATION OF PLATE XII.

Figs. 1, 2.—Photomicrographs of the holotype. × 5·4.
Fig. 3.—Photomicrograph of vertical section of a paratype. × 5·4.

Some Lower Cretaceous Corals from Eastern Venezuela.

By J. W. Gregory, D.Sc., F.R.S.

(PLATE XIII.)

Mr. J. V. HARRISON, B.Sc., has recently collected some coral limestones from two localities in Venezuela, which he has entrusted to me for identification and description. The corals indicate the existence in eastern Venezuela of a rich fauna, for the specimens include fragments of seven genera. Some of the corals are too small for specific, and some for certain generic determination; but as there appears no likelihood of further material being collected, it seems advisable to describe what is available to direct attention to an interesting and varied coral fauna. The two localities represented are Port Piritu, on the shore of the great bay west of the town of Barcelona in eastern Venezuela, and Punceres to the west of the Gulf of Paria between the two branches of the Rio San Juan and due west of the lower course of that river. A map, for which I am indebted to the Anglo-Persian Oil Co., through Mr. S. Lister James, shows that the position of Punceres is at about 10° N., 63½° W. The corals were collected during surveys made for that Company, which has paid for the accompanying plate.

I. Urgovian Corals from Port Piritu.

(1) *Thecosmilia* cf. *tobleri* Koby, 1897. *Polyp. crét. Suisse* (*Mém. Soc. Pal. Suisse*, xxiii), p. 38, pl. xiii, f. 1–4.

Neocomian—Bannalp, Switzerland. Urgovian—Port Piritu, Eastern Venezuela.

In the Swiss specimens the diameter of the branches is from 10 to 30 mm.; one specimen from Port Piritu has branches 24 by 29 mm. thick. An allied species is *T. irregulare* Etallon (cf. Ogilvie, 1897, *Kor. Stramberg, Pal. Mitth.*, iii, p. 209, pl. 14, f. 6) which has a smaller stem, the diameter being given by Ogilvie as 10 mm.

(2) *Stylosmilia alpina* ? Koby, 1897. *Polyp. crét. Suisse*, p. 36, pl. vii, f. 6–7.

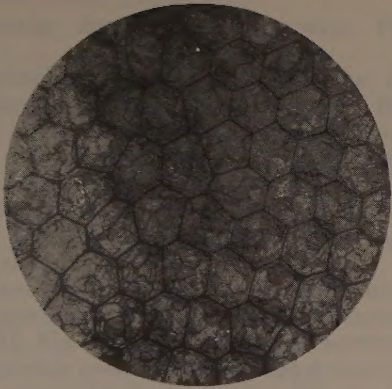

FIG. 1.

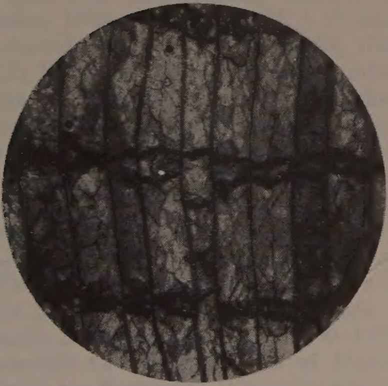

FIG. 2.

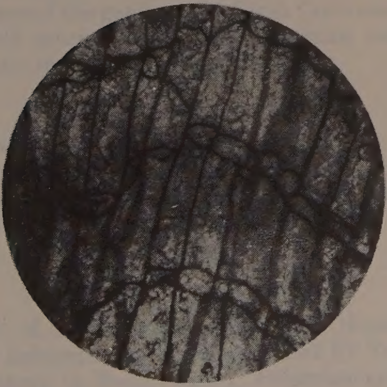

FIG 3.

A NEW GENUS OF TABULATE CORALS.

[To face p. 440.

This coral has small stems 1·5 mm. in diameter. That of the type specimens of *S. alpina* is from 2 to 2½ mm.

Neocomian—Bannalp, Switzerland. Urgovian—Port Piritu, Eastern Venezuela.

(3) *Diplarea venezuelensis* n.sp. *Diagnosis.*—The dichotomous branches form a large open caespitose corallum. Branches are circular or elliptical in cross section, and sometimes trigonal near the bifurcations. The septa are perforate to the outer edge, and are very thin; seven orders are represented, of which most of those of the first five orders reach the columella. The usual number of septa is about 72. The columella is large and occupies about one-third of the diameter of the corallite.

Dimensions.—Branches up to 10 by 15 mm. in diameter.

Distribution.—Urgovian, Port Piritu, Eastern Venezuela.

Figures.—Pl. XIII, Fig. 1*a*, part of a polished section, × 3 dia.; Fig. 1*b*, section of another corallite on the same specimen, × 3 dia.

Affinities.—This species is most closely akin to *D. subcrassa* (Koby, *Pol. jur. Suisse*, 1889, p. 475, pl. 124, f. 5) from the Swiss Corallian and also described by Dr. Ogilvie (1897, *Kor. Stramberg*, p. 259, pl. xi, f. 18) from the Tithonian of Stramberg; in that species, however, the corallites are larger, the branches being from 12–20 mm. in diameter, and the septa more numerous, being from 80–100. The septa in *D. subcrassa* also taper less evenly and only from 24–30 reach the columella. In *D. venezuelensis* the septa are less numerous, but a higher proportion reaches the columella. Of the *Diplarea* described by Koby the new species is most nearly related to *Diplarea laxata* (Thurm. and Et.), 1862; Koby, *Dermosmilia laxata*, 1884, *Polyp. jur. Suisse*, p. 195, pl. 51, f. 1–5. *D. laxata* has somewhat larger branches which are 12–15 mm. in diameter, and its septa are more numerous, being from 80–100. Koby has described as *Dermosmilia* two other species of *Diplarea* (Ogilvie, op. cit., pp. 258–9) from the Sequanian (Upper Corallian) of Switzerland, but does not record the genus in the Swiss Cretaceous. *D. venezuelensis* is decidedly more allied to the Tithonian *subcrassa* than to the earlier Jurassic representatives of the genus.

4. *Metethmos* ? sp.

A coral with well-preserved internal structure is generically indeterminable as it is doubtful whether the coral is simple or is a fragment of a compound branching coral. If simple, it would be a *Metethmos* (Gregory, *Jur. Corals Cutch*, *Pal. Indica*, (9), ii, 1900, p. 165).

5. *Thamnarea* or *Dimorpharea.*

A small fragment of a coral belongs to one of these genera. A species, *Thamnarea holmoides*, has been described by Felix from the Neocomian of Tehuacan in Mexico (1891, *Paleontographica*, xxxvii, p. 143, pl. xxii, f. 1).

II. CORALS FROM PUNCERES.

1. *Diplocoenia occidentalis* n.sp.

Diagnosis.—Corallum massive with an even upper surface. The corallites are large, 10–12 mm. in diameter, circular to elliptical, with the inner wall incomplete. Calices shallow; septa with four orders nearly complete; the septa of the second and third orders and sometimes some of the fourth order unite with the primary septa. The columella is large and elliptical.

Dimensions.—The species is represented by a fragment 100 by 50 by 40 mm.; corallites 10–12 mm. diameter. The diameter within the inner wall is 6 mm.

Pl. XIII, Fig. 3*a*. Part of the surface of a corallum, × 1½ dia. Fig. 3*b*. Transverse section cut from the same specimen, × 4 dia. Fig. 3*c*. Part of another section, showing the elliptical columella and the grouped arrangement of the septa, × 4 dia.

Distribution.—Probably Urgovian; Punceres, Eastern Venezuela.

The genus *Diplocoenia* has a double walled structure, which is well shown in the original species from the Cretaceous of France. This Venezuelan species differs from the three best known European species by the much larger size of its corallites. It is probably nearest to the *D. saltensis* of de Fromentel, *Pal. franc.*, *Terr. crét.*, *Polyp.*, 1879, p. 511, pl. 127, f. 2, in which, however, the calices are only 2 mm. in diameter, and the septa fewer being only 24 in each corallite, and only a few join the columella. It differs from *D. picteti* Koby (1896, *Polyp. crét. Suisse*, p. 24, pl. 5, f. 7–8) from the Urgovian of Reignier in Switzerland, which also has small calices 2 mm. in diameter. The calices in *D. picteti* are also deeper and are separated by a ridge instead of by a flat space between the inner walls. The irregular development of the inner ends of the septa in *D. picteti* gives the appearance of pali; and the septa of the third order are described as almost rudimentary, and do not join the primary septa as do some of those of *D. occidentalis*. The name of the new species is suggested as it is a western development of the European species. The second wall is incomplete, but parts of it are indicated in the magnified section, Pl. XIII, Fig. 3*c*.

2. *Thamnastrea harrisoni* n.sp.

Diagnosis.—Corallum massive. Corallites small, separated on the surface by a well-marked groove or a well-defined raised wall. The corallites are angular and frequently pentagonal. The wall in the interior of the corallum is well developed. Septa, three orders represented; the first 12 septa join the columella which is distinct; the septa of the third order are short and do not reach the columella.

Dimensions.—The fragment of the corallum measures 100 × 80 × 70 mm. Corallites 2 mm. diameter.

Distribution.—Urgovian; Punceres, Eastern Venezuela.

Figures.—Pl. XIII, Fig. 2*a*, part of the surface, × 2 dia. ; Fig. 2*b*, urface of another part of the same corallum, × 4 dia. ; Fig. 2*c*, part of a thin section, × 5 dia.

Affinities.—This species is closely related to *Thamnastrea urgonensis* Koby (1898, *Polyp. crét. Suisse*, p. 82, pl. xix, f. 4–8, pl. xx, f. 1, 2) with which I was at first disposed to identify it. *T. urgonensis* Koby, however, has even smaller corallites, as the distance of the calicinal centres is from $\frac{1}{2}$ to 1 mm. ; the wall is less distinct ; he surface lacks the angular groove between the calices ; the septa n the surface are developed as continuous septo-costae. There is lso no evidence that *T. harrisoni* is pedunculate.

III. Correlation of the Faunas.

Whether these two coral limestones belong to the same horizon he evidence is inadequate to determine. Not one species is common o both, perhaps because so few are known from each locality. The Port Piritu fauna is the more varied. Some of its corals have affinities o the Upper Jurassic, but the determinable species are Lower Cretaceous, and either Neocomian or Urgovian. Of the two species rom Punceres, one is most nearly allied to a French Neocomian nd the other to a Swiss Urgovian species. The difference of both aunas from the Mexican Neocomian corals described by Felix *Paleontographica*, xxxvii, 1891, pp. 142–62) suggests that the fauna s not Neocomian. So far as the available evidence serves, I am nclined to regard both faunas as of approximately the same age, nd as more likely Urgovian than Neocomian. The corals, on irst examination, reminded me most of the Stramberg fauna from he Portlandian or uppermost Jurassic rocks of the northern Carathians (cf. M. M. Ogilvie, *Die Korallen der Stramberger Schichten*, *Pal. Mitt.*, iii, 1897, pp. 73–282) ; further examination showed hat the affinities are Lower Cretaceous. The fossils represent a orizon lower in the Cretaceous than any marine bed recorded from Eastern Venezuela. A. Jahn's geological map (*Esbozo de las ormaciones geologicos de Venezuela*, 1921) marks the beds at Port Piritu as Upper Kainozoic and throws no light on the coral limestone. H. Karsten (*Zeit. deut. geol. Ges.*, ii, 1850, p. 87) mentions the ccurrence of Kainozoic echinoids at Piritu and recognizes Cretaceous eds containing Inoceramus, Ammonites, and coal. Karsten in the ap accompanying a second note (ibid., pp. 345–61, pl. xi) shows a and of the older Cretaceous rocks to the W.S.W. of Port Piritu rossing the Unare River, north of Clarines ; and he represents hese beds as the core of an anticline and as flanked by later retaceous beds. W. Sievers (*Zweite Reise in Venezuela in den ahren*, 1892–3, *Mitt. geogr. Ges.*, Hamburg, xii, 1896, pp. 218–30) escribed the bay on which Port Piritu occurs as due to a foundered lock and (ibid., p. 227) the hill there, 468 m. high, as composed of Upper Cretaceous red sandstone with conglomerates. G. P. Wall *Q.J.G.S.*, 1860, xvi, p. 460, map pl. 21) showed a band of his Older

Parian Formation extending from western Venezuela almost as far east as Piritu. He assigned this formation to the Neocomian on general grounds and mentioned no corals in them. Gerhardt (*N. Jahrb. Min.*, Beil. Bd., xi, 1897, pp. 65–116) described some Venezuelan Cretaceous fossils, but he did not record any corals; and the beds he referred to the Lower Cretaceous are red sandstones of Baremian or Upper Neocomian age. The Inoceramus beds mentioned by Karsten may be Middle Cretaceous and widely spread in Venezuela. They include the Segovia beds of L. V. Dalton (GEOL. MAG., 1912, p. 209), who regarded them as ranging from Neocomian to Aptian.

So far therefore as I know the literature, the occurrence of a Lower Cretaceous coral limestone is new to eastern Venezuela. The corals in these limestones are so fragmentary that they do not justify any final opinion as to their precise age; but so far as can be judged from the specimens the two coral limestones belong to about the same horizon, which may be regarded as approximately Urgovian.

The Earth's Thermal History.

By HAROLD JEFFREYS.

PROFESSOR HOLMES'S further article,[1] substantiating points questioned by me,[2] may be divided into two parts. In the first he gives a statement of some geological phenomena not yet explained in accordance with his old theory of the earth's thermal history. In the second he maintains that these demand the abandonment of the theory and its replacement by a new one, which I consider qualitatively wrong. With regard to the first part, I consider that Professor Holmes has done a great service to geophysics in bringing these points forward in so clear a way. It has never been claimed that the old theory explained everything, and in some points it certainly requires to be supplemented; the questions at issue are what modifications are required, and whether they are such as to change the whole character of the earth's thermal history. But before problems can be solved it is necessary that they should be stated, which is liable to be at least as difficult.

The majority of Professor Holmes's points are related to the possibility of fusion at depths less than about 30 km. He seems to me to have here fallen into a common geological confusion, namely, the assumption that the average plutonic rock known to geology is also the average rock of the earth's crust. The earth is so far as we know, rocky in constitution to a depth of 2,900 km. The upper 30 km. make up little more than one per cent of the

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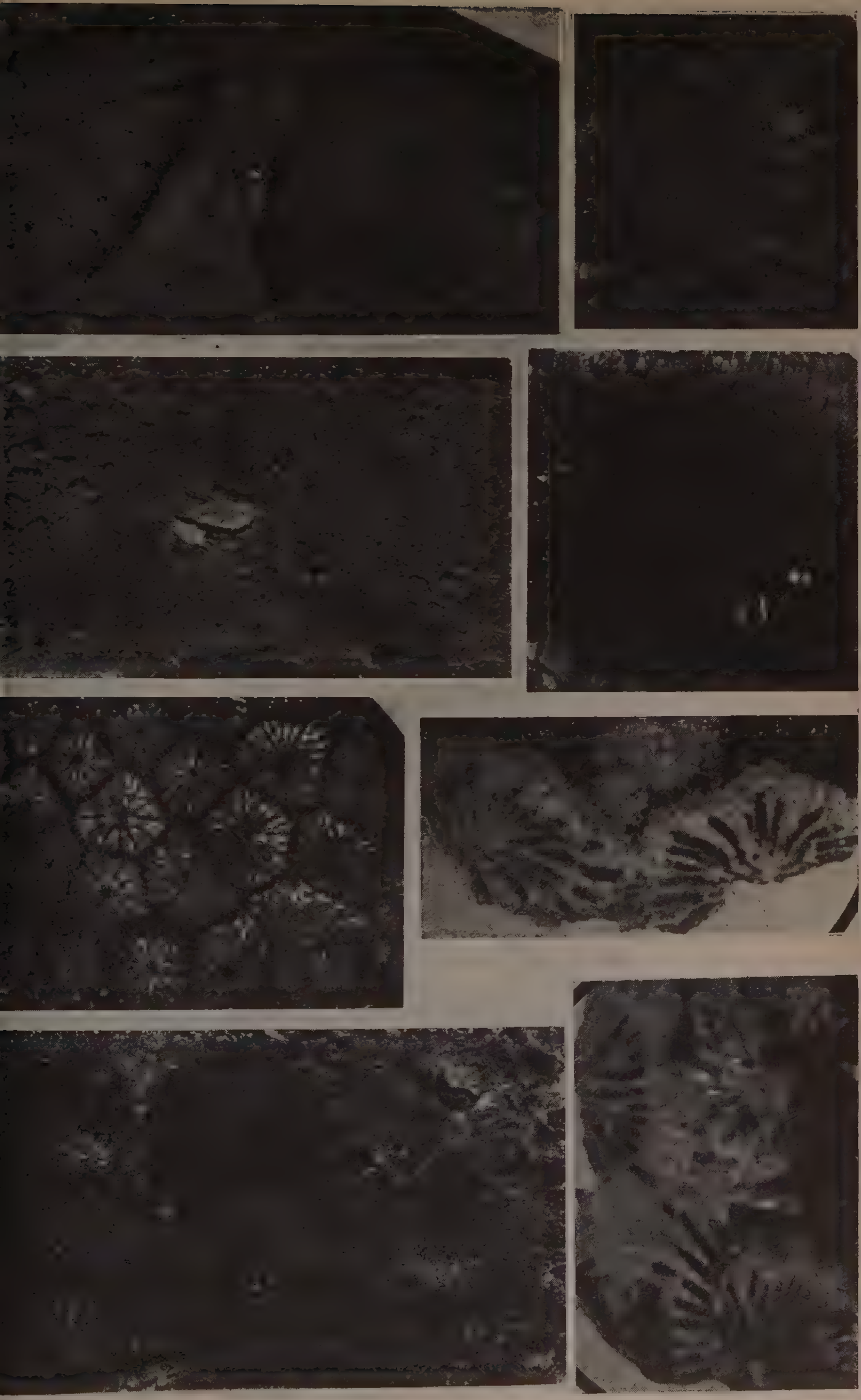
[1] GEOL. MAG., June, 1927, 263–78.

[2] GEOL. MAG., November, 1926, 516–25.



Cretaceous Corals from Venezuela.

[*To face p.* 44

whole, and if it was absorbed into it a careful analysis would be necessary to detect any difference. This point is also relevant to the widely expressed view that the primary magma is basaltic, and that granitic and ultrabasic rocks have been derived from this by differentiation. If the crust below the basaltic layer is ultrabasic, then the primitive magma, if it was ever undifferentiated, was also ultrabasic, and the great problem of petrogenesis is to find out how granitic and basaltic rocks both separated from solution or combination in an ultrabasic magma. In Professor Holmes's article, p. 273, he says that "the introduction of sufficient heat to generate magmas on the scale and in the variety disclosed by geological history completely upsets the hypothesis of continuous cooling, whether the heat be of radioactive origin or not". But these magmas concern only part of the uppermost 30 km. This could be heated to fusion again and again without greatly affecting the thermal history of the 2,900 km. below it, for heat generated at small depths is rapidly conducted to the surface and radiated away, and then the process resumes its normal course. A little earlier he remarks that the crystallization of a magma below demands the pre-existence of a magma to crystallize, and claims radioactive heating as the most plausible explanation of such a magma. But if we accept the view that the earth was originally molten 2,900 km. of magma are available without further explanation.

The effects of change of state are investigated to some extent in a forthcoming paper of mine.[1] The most probable course of events seems to be that stiffening extends downwards gradually, so that at any stage there are an upper layer too stiff to permit convection currents, and a lower one where redistribution of heat by convection is still effective. The numerical results depend on the latent heat of the change of state and are therefore very provisional. If the change was from a true liquid to crystals, the depth of the crystalline layer should be now about 300 km. If the change is from a liquevitreous state to a durovitreous one, the depth may be much greater. Two notable changes in the previous theory of the earth's thermal history are indicated. An increase in the available compression arises from the change of state, and also its distribution in time is modified. The compression originally increases like the square root of the time as on the ordinary theory, but in an interval of the order of 10^9 years it gradually changes till it varies linearly with the time. Holmes's objection that the existing theory implies too much mountain formation in early geological time in comparison with that in the Tertiary period may therefore be met in this way.

The stiff upper layer reaches up to the asthenosphere, and must in any case be weak. Further, the first effect of cooling after solidification is to produce a horizontal tension, which may facilitate the passage upwards of any chemically active gases liberated during the change of state.

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[1] Gerlands Beiträge z. Geophysik 17, 1927.

Holmes's difficulty that the intermediate layer of seismology, that is, the one between depths of 10 and 30 km., would be too cold on the existing theory to permit igneous activity, disappears if we admit the possibility of local and temporary heating. Some support for the view that the heating has these properties is supplied by evidence from the history of mountain ranges that the ordinary viscosity of this layer is of the order of 10^{22} or 10^{23} c.g.s., as against a probable 10^{14} for hard glass at 500° ; the layer is stiffer than we should expect from the temperature attributed to it by the theory, not softer.

These new results are subject to a certain amount of numerical alteration, but on the whole they seem to justify hopes concerning the power of the theory of continuous cooling to account for the phenomena discussed by Holmes.

Coming to the theory of magmatic cycles, Holmes admits that the theory has not yet been expressed satisfactorily from a physical point of view. Since this is the whole of my criticism of it, it appears that his opinion and mine of the present state of the theory do not differ as greatly as might appear at first sight ; our difference is really in our degrees of optimism concerning its future. In particular I should hesitate to accept the view that mere complication would affect the possibility of resolidification after fusicn by excess of radioactivity. If the resources of a laboratory are insufficient to devise a system that will behave in the desired way, one feels doubtful as to whether the earth is such a system. Most of the sources of complexity mentioned by Holmes are indeed available to the old theory just as well as to the new one.

On the Relations between Silica, Alumina, and the Bases in Eruptive Rocks, considered as a Means of Classification.

By S. J. Shand, Stellenbosch, South Africa.

THE Geological Magazine did me the honour in 1914 to publish a paper in which I proposed a classification of eruptive rocks on the basis of the " degree of saturation" of the constituent minerals with silica. Any mineral which is proved by its field associations to be stable in the presence of free silica, under such conditions as prevail in natural rock magmas, was said to be " saturated " with regard to silica. Other minerals, such as leucite and olivine, which are not stable in presence of free silica, within the ordinary range of magmatic temperatures, were said to be " unsaturated " with regard to silica. Eruptive rocks were then classified as " oversaturated ", if they contained quartz or tridymite ; " undersaturated", if they contained any unsaturated minerals; and "saturated" if neither free silica nor any unsaturated mineral was present.

I make no claim for originality in this matter, although, when I wrote the paper referred to, I had no knowledge of any earlier proposal of the same nature. The greatest petrographer the world has ever seen, Ferdinand Zirkel, proposed as long ago as 1873 to separate the quartz-orthoclase rocks from the orthoclase rocks without quartz, and these from the orthoclase-nepheline rocks, and the plagioclase-augite rocks from the plagioclase-olivine ones. F. Loewinson-Lessing claims to have put forward a classification of oversaturated, saturated, and undersaturated rocks in Russia in 1890. J. Morozewicz referred in 1898 to the possibility of classifying rocks by the degree of saturation with silica, and also with alumina, but he did not elaborate his proposal.

In my 1914 paper I went only a little further than Zirkel did in 1873; for in addition to leucite, nepheline, the sodalite group, olivine and melilite, all of which Zirkel recognized to be incompatible with quartz, I added a few other minerals, such as analcime and cancrinite, melanite, and pyrope, corundum, and calcite, to the "unsaturated" list. The evidence for the unsaturated character of the various minerals on this list was discussed in the 1914 paper and in several sequels which made their appearance in the GEOLOGICAL MAGAZINE during 1915 and 1916, and it is summarized and brought up to date in my larger work, recently published.[1]

The special advantages of this method of classifying rocks are that it contains no arbitrary or subjective element; that it is based on hard facts of mineral chemistry; and that it furnishes clean-cut groups of rocks, of each of which it is possible to say positively that certain minerals are possible constituents and that certain others are excluded.

In my recent book on eruptive rocks, I have tried to take a further step in the direction of setting petrography on a firm, chemical basis. My account of this step seems to have presented difficulties to a reviewer in the GEOLOGICAL MAGAZINE, so I should like to explain it once more, as clearly as I can.

After silica, alumina is the most abundant oxide in nearly all eruptive rocks. J. Morozewicz pointed out in 1898 that it would be possible to classify rocks as oversaturated, saturated, or unsaturated with alumina, but he did not show how his suggestion was to be put into effect. It is much more difficult to classify rocks according to the degree of saturation with alumina than according to the degree of saturation with silica. The method which has seemed practicable to me, and which I have worked out in my book, is based on the following considerations.

1. When the molecular proportion of alumina in a rock exceeds

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[1] *Eruptive Rocks*, London, 1927.

the molecular proportions of soda, potash, and lime combined, the excess of alumina goes into one or other of the following minerals:—Corundum, topaz, tourmaline, spessartite, almandine, muscovite, biotite. Rocks containing any of these silicates, without any other dark silicate, are said to be *peraluminous*.

2. When the molecular proportion of alumina in a rock is equal to or greater than the molecular proportions of soda and potash combined, but less than soda, potash, and lime combined, then some of the following minerals must be developed:—Non-aluminous pyroxene, or amphibole, aluminous pyroxene or amphibole, olivine, melilite, epidote; or else one of these minerals together with biotite. The wide range of mineral associations possible in this case has been subdivided in the following way:—

> (*a*) Rocks containing hornblende, melilite, or epidote; or containing a pyroxene or olivine together with biotite, are said to be *metaluminous*.
>
> (*b*) Rocks containing ortho- or clino-pyroxene, or olivine, without appreciable quantities of hornblende or biotite, are said to be *subaluminous*.

3. When the molecular proportion of alumina in a rock is less than the molecular proportions of soda and potash combined, then some of the following minerals must be developed:—Aegirine, soda-diopside, riebeckite, arfvedsonite, eudialyte, pectolite, and other uncommon species. Rocks containing any of these minerals are said to be *peralkaline*.

The advantages of this method of classification, in the writer's eyes, are that it brings all the possible dark silicates, which have not hitherto been grouped, for petrographic purposes, in any systematic way, into four large groups, within each of which the characteristic minerals have more in common with each other, as regards both chemical composition and conditions of formation, than they have with the minerals of the other groups. Thus the peraluminous minerals, as a whole, are especially characteristic of pegmatites and facies of late crystallization. The metaluminous group contains minerals which are formed at relatively low temperature in presence of water (hydatogenetic minerals). The subaluminous group contains only minerals which can be formed by dry fusion (pyrogenetic minerals). The peralkaline group holds the characteristic minerals of the soda-granites and foyaites.

This method of classification, like that based on silica saturation, is free from any subjective element, and it is based on a prominent chemical distinction. It furnishes groups which are in general well defined and easily distinguished, and the method can even be applied to glassy rocks, if a reliable chemical analysis is available. (The procedure, in this case, is to calculate the "norm", and then to deduce the peralkaline, peraluminous, metaluminous, or subaluminous character of the rock from the presence of (*a*) acmite, (*b*) corundum, (*c*) corundum and hypersthene, (*d*) pyroxene without corundum in the norm.)

In conclusion, I believe that the method of classifying rocks according to the relations between silica, alumina, and bases, possesses many great advantages over any other method that has yet been tried. It goes further than any other method in the direction of correlating mineralogical with chemical characters, and its employment will impart to systematic petrography something of the qualities of precise definition and of chemical significance that are so conspicuously lacking at the present time.

I am well aware that there are petrologists, and among them some of the best and most philosophical, who think it a waste of time to discuss problems of classification. They believe that in the course of time a genetic classification of rocks will gradually unfold itself, which will supersede all our present methods. I am in full sympathy with the desire for such a classification, but I do not see how a slipshod and ambiguous nomenclature can ever help us to attain it. Nor should it be forgotten, that even when we have a classification which tells us *how things originated*, we shall still require another to tell us *what they are*. Animals and plants have two names—a generic one, which, in a perfect system, would indicate the line of development, and a specific one, which is simply descriptive. The two are complementary, not antagonistic.

Few people seem to realize that classification stands towards science in the same relation as book-keeping towards business. What would happen to a bank if the staff kept their books as we keep ours? "Mr. X has drawn out a considerable quantity of gold. The amount deposited by Mr. Y. is approximately the same as that credited to Mr. Z., according to the senior partner, but the junior partner thinks it is less. The account of Mr. P. typically shows no credit whatever, but it may record either a small deposit or an appreciable overdraft."

Childish, is it? Fantastic, is it? Yet it strikes me as being remarkably like the condition of petrography at the present day!

Cauldrons of Subsidence.

By Professor E. H. L. Schwarz, Rhodes University College, Grahamstown.

IN their memoir on the Cauldron Subsidence of Glencoe,[1] the authors, Messrs. Bailey, Clough, and Maufe, showed that the structure owes its origin to a cylinder that has sunk; around the edges there are various crush phenomena, culminating in fusion and actual lava. Alongside Glencoe is the granite mountain of Glen Etive, defined by a circular fault, and thus representing a cylinder that has been pushed up. The authors discuss the bearing of their work on general questions of geology; they show that the cylinder may simply sink, and the top be covered with the rocks originally in place upon it. Branca described a similar case in the Ries in Swabia.[1] In others the circular fault has served as the orifice from which lava has been poured over the floor of the pit, as in the Hegau.

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[1] *Q.J.G.S.*, vol. lxv, 1909, p. 611.

The Ries is 15½ miles in diameter, and is accompanied on the south by a half-moon shaped depression, the Vor-Ries. The main pit is in white Jurassic limestone, which is exposed in the cliffs surrounding the depression, forming a continuous wall from 300 to 350 feet high. The floor is covered with Tertiary freshwater deposits; below are granite and gneiss, pierced by dykes of mica-trap. Round the edges there are evidences of great pressure in the crush-breccias and the over-thrusting of the strata; while, in addition, there is much volcanic ash, lava-bombs, and other ejectamenta. The tuff in places is cemented with deposits of zeolites, carbonate of lime, and tridymite; some of the ash is purely volcanic, but much of it consists of broken-up fragments of the underlying granite. For all its present shape as a pit, the Ries is a mountain. The floor of granite is 300 to 350 feet below the surrounding country, but outside the granite is only struck in bore-holes at 1,300 feet.

Other similar pits are found at Herresheim and between Ellenberg and Bopfingen, the latter 18 square miles in area; right away at the south-western end of the Swabian mountains is the Hegau. It is 11 miles in diameter and though the walls are of limestone, as in the Ries, the floor is made of basalt, melilite-basalt, and phonolite. The lava never overflowed the lip of the pit, but the whole country around is covered with tuffs that were blown out of these volcanoes. Between the Ries and Hegau are Branca's 125 embryonic volcanoes.

Sometimes the cylinder splits in two across the centre, and one side may be higher than the other; the expiring volcanic forces then vent themselves on this fissure; a chimney is drilled along it, and a volcanic cone forms in the centre of the depression.

The relationship of these circular depressions to pit-faults was dealt with when describing the Baviaans' Kloof area in Willowmore, Cape of Good Hope.[2] Under horizontal torsion, the earth's crust is faulted in two directions at right angles, or at angles that are within a few degrees of 90. In the Baviaans' Kloof area, portions from 2 to 15 miles long, and from 1 to 5 miles across, have been let down, with walls 400 to 800 feet high all round. In the larger basin in which the town of Uitenhage lies, Dr. Haughton has mapped a vertical fissure filled with basalt, continuing the line originally found by Dr. Rogers, and defining the boundary-fault along approximately half its length. There are some twenty of these fault-pits along the south-western part of the Cape Province, but only a few are actual hollows now ; most of them contain Cretaceous deposits, and the rivers flowing across them, finding the lip of rock on the far side as hard as that by which they enter the area of soft deposits, simply wander over the surface. It is only in Baviaans' Kloof that the unconsolidated sands and gravels have been scooped out; and we can examine the walls of the pits. The transition from the elongated Rift Valleys to the Fault-pits, and from these to the circular cylinders, can be traced through all stages of gradation.

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[1] W. Branca, *Schwabens* 125 *Vulcan-Embryonen*, 1894; W. Gümbel, *Geognostische Beschreibung der frankischen Alb*, 1891; W. von Knebel, "Studien uber die vulkanischen Phänomene im Nördlingen Ries": *Zeit. d. deutsch. geol. Ges.*, Bd. 55, 1903, p. 236.

[2] E. H. L. Schwarz, *Ann. Rept. Geol. Survey*, Cape Town, 1904; p. 119. *B. Assoc. for Adv. Sci.*, 1905; *Causal Geology*, London, 1910; *South African Geology*, 2nd ed., 1927.

In South-West Africa there is Geitsi Gubib, 2 miles in diameter, a cylinder that has sunk, bending down the Fish River Rand beds around it, but the bedded debris in the pit has been tilted up along the edges.[1] The Salt Pan north of Pretoria is a much smaller affair, but with a well-defined inner circular fault, making a terrace, or step, down from the outer margin to the bottom.[2]

Pilandsberg is 18 miles across, with several concentric faults up which lavas of various kinds of nepheline rocks have issued ; the floor of the pit is filled up with tuffs and lavas.[3] The fourth great cylinder is the Vredefort Mountain Land, a huge cylinder of granite, 25 miles in diameter, thrust up through Lower Witwatersrand Beds, which they have partially fused by frictional heat.[4]

In Central Africa, Barnes has described the Giant Craters on Lake Eyassie: the biggest is Ngorongoro, 12 miles across.[5] It lies on the Engotiek Plateau, 75 miles west of Arusha, and west of Kilimanjaro. On the north there is a saucer-like plateau with walls broken down but still suggesting a crater ring ; it is covered with hummocky grass, forming a treeless moor amidst dense forest. Its elevation is 7,000 feet above sea-level, and it is some 10 miles across. This couple is wonderfully reproduced in the lunar structure Wargentin, which is a cylinder up, representing the elevated moor, while the pit alongside is a replica of Ngorongoro itself.

On the north-west this plain is bordered by the Ololmoti volcanic cone and the chasm of the giant crater itself. This is sunk 4,000 feet below the plain, and is entirely surrounded by precipitous cliffs. In the floor is the Magad lake, with the volcano Oldeani rising above it, with a crater 3½ miles in diameter.

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[1] *Trans. Roy. Soc. S. Africa*, Cape Town, 1915, p. 102; P. A. Wagner, *Geol. Survey Memoir*, 7, Pretoria, 1916, p. 72.

[2] P. A. Wagner, *Geol. Surv. Memoir*, 20, Pretoria, 1924.

[3] W. A. Humphrey, *Rept. Geological Survey for* 1911, Pretoria, 1912, pt. iv.

[4] A. L. Hall and G. A. F. Molengraaff, *Mem. Roy. Acad. Sci. Amsterdam*, 1925, 2nd section, pt. xxiv, No. 3.

[5] T. A. Barnes, "The Highlands of the Giant Craters," *Geogr. Journ.*, 1921, p. 401; F. Jaeger, "Das Hochland der Riesenkrater," *Mitth. a.d. deutsch. Schutzgebieten.*

Myriads of antelopes and other big game graze on the floor of Ngorongoro and never leave it, for the ground is covered with luxuriant clover, affording ample food for the vast herds. For 60 miles in a north-easterly direction between the Oldonyo Langai (Doinyo Ngai, the Mountain of God) and Gelei, lies a steaming, desolate, grey, mud-plastered country, presenting the same features that once existed right across the volcanic mass of Engotiek, when the giant craters were erupting and showering ash over everything, and giving one a vivid reproduction of Swabia when the Ries and Hegau were in operation.

In the Sahara there is Emi Koussi, described by Colonel Tilho, 10,000 feet high and 5 miles in one diameter and 8 in another. In Madagascar there are plugs of eleaolite-syenite similar to the Pilandsberg rocks at Be-zavona, on the west coast; but the best parallel is Atandroy, on the south. It is a basaltic volcano, with lofty hills surrounding a quadrangular crater-pit, open to the south, so that the rim is horse-shoe shaped, like the Hegau. It is 15½ miles in diameter, and the central peak rises to 2,625 feet. The hills of the rim are called by separate names, I-vato-malamo, Be-vovo, I-vohits-osy, I-babaka, Be-nonoka, An-ala-lava, An-afitisa, and so on, in the liquid language of Polynesia; the central hill is called I-vohitso-be. The square outline of this volcano recalls the Askja volcano of Iceland, the Erongo Mountains of South-West Africa, and the Ahaggar of the central Sahara.[1]

Other giant craters are the Aso, on the island of Kiushiu, Japan; a nameless one in Kamschatka, and Lake Bombon in the Philippine Islands. All of these are about 15 miles in diameter. Lake Bolseno, in Italy, is 10.

Turning to the moon, the split cylinder of Petavius, Fig. 1, has been known for a very long time, but this cross-fracture has not been connected with the central peaks. The explanation of the authors of the memoir on the Cauldron Subsidence of Glencoe is a perfectly sound one; but as the floor is covered with lava in most of the crater rings showing the central peak, and thus the fracture, if it is there, is hidden, the application of their work to such structures has not been grasped.

Recent observation in Grahamstown has shown that the Straight Wall in the moon is an example of the same splitting of the cylinder. As this great fault rises to a maximum in the centre and dies away at either side, it shows an anticlinal structure, thus reproducing on a large scale the condition of affairs in the crypto-volcanic pit of Steinheim. This is a circular depression 1½ miles in diameter, 260 feet deep, with the Klosterberg rising in the centre to a height of 132 feet ; the hill is formed by a quaqua-versal anticline of white and brown Jura.[1] The idea is that a plunger of granite, or whatever rock underlies the Jurassic sediments, was forced up and caused the limestones to assume a dome shape within the margins of the cylindrical depression ; first there was a sinking and then an elevation. In this connexion we have a similar pushing upwards of a cylinder in the spine of Mount Pelée, which was actually seen to rise. It was made of solidified lava, but the same principle

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[1] E. F. Gautier, *Madagascar*, 1902.

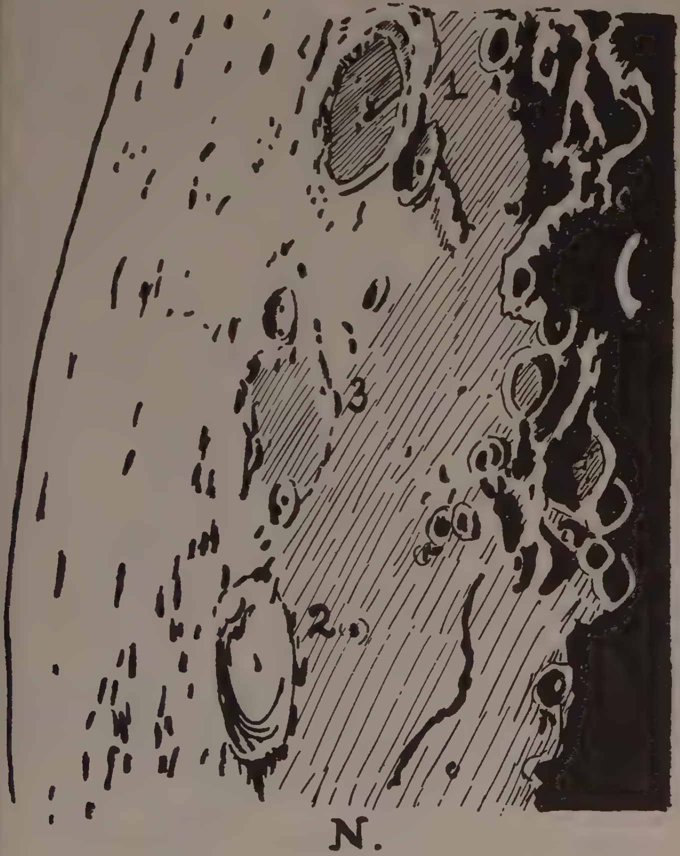

Fig. 1.—The Moon's surface. Fourth Quadrant, showing (1) Petavius with the split cylinder and very broad terraces ; (2) Langrenus with the central curve and broad terraces ; (3) Vendelinus.

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[1] W. Branca and E. Fraas, " Das kryptovulkanische Becken von Steinheim " : *Abhandl. d.k. preuss. Akad. d. Wiss.*, Berlin, 1905.

would act if the plug were made of a torsion cylinder, loosened by circular faults.

There are cylinders on the moon in all stages, and of all sizes. Some just roughed out, without any differential movement, others developed into well-defined crater-rings, with step-faults round the margins forming inner and outer terraces. The action during the formation of these torsion cylinders may be likened to that of rolling a lump of putty between one's hands. Outside the rings of the craters may be seen the crossing shear-planes along which the movement responsible for the creation of the cylinders acted; they are mostly filled with what appears to be viscous lava, extruded and solidified in long lines of ridges.

The next stage is for the torsion cylinder to be heaved up like the piston of a pump, by hydraulic pressure of the molten rock below. Lava rises round the plug, and cements it in place, and as the whole cools down, an inner concentric fault develops. When the next paroxysm occurs, the accession of pressure forces the inner core up, leaving the outer rim as an elevated shell—somewhat after the manner of the joint of a telescope. Lava may be extruded from the fissure and pour over the sides, but at any rate, the inner core is anchored into its position by the molten rock as it cools. This action may go on till half a dozen or more terraces are formed round the central core. Then the volcanic action dies down, or is transferred to another region; the liquid substratum is drawn off, leaving the plug suspended and loose, from the development of the concentric cracks. It falls, and plunges into the molten rock, which spurts up the sides, giving rise to small volcanoes, or to sheet-effusions of lava. This, again, may be repeated several times, each stage being marked by an inner terrace. When this has gone on to the limit, the cylinder touches bottom, and splits in two. One is at a loss to explain this phenomenon, but it is paralleled by a block of granite or dolerite exposed to desert weathering; at first successive shells are scaled off, by the development of concentric cracks brought about by expansion and contraction under the sun's heat, and finally the block splits in half.

The last efforts of the expiring volcanic forces in the cylinder are directed towards expelling gases up the central fissure, scoring out one or more chimneys, and piling up an ash and lava cone, or a row of such peaks.

In the meridianal line of the moon, Fig. 2, there are three very famous crater-rings in a row. Ptolemaeus, at the north end, is the largest, with a diameter of 114·8 miles, and an area of 8,500 square miles, being a transition in size between the smaller crater-rings and the circular seas, or lava-plains. The walls rise on an average 3,000 feet above the smooth interior, with one peak in the north-western corner 8,800 feet. The surface is covered with low waves of lava, rising 100 feet from trough to crest, while there are innumerable tiny craterlets scattered all over.

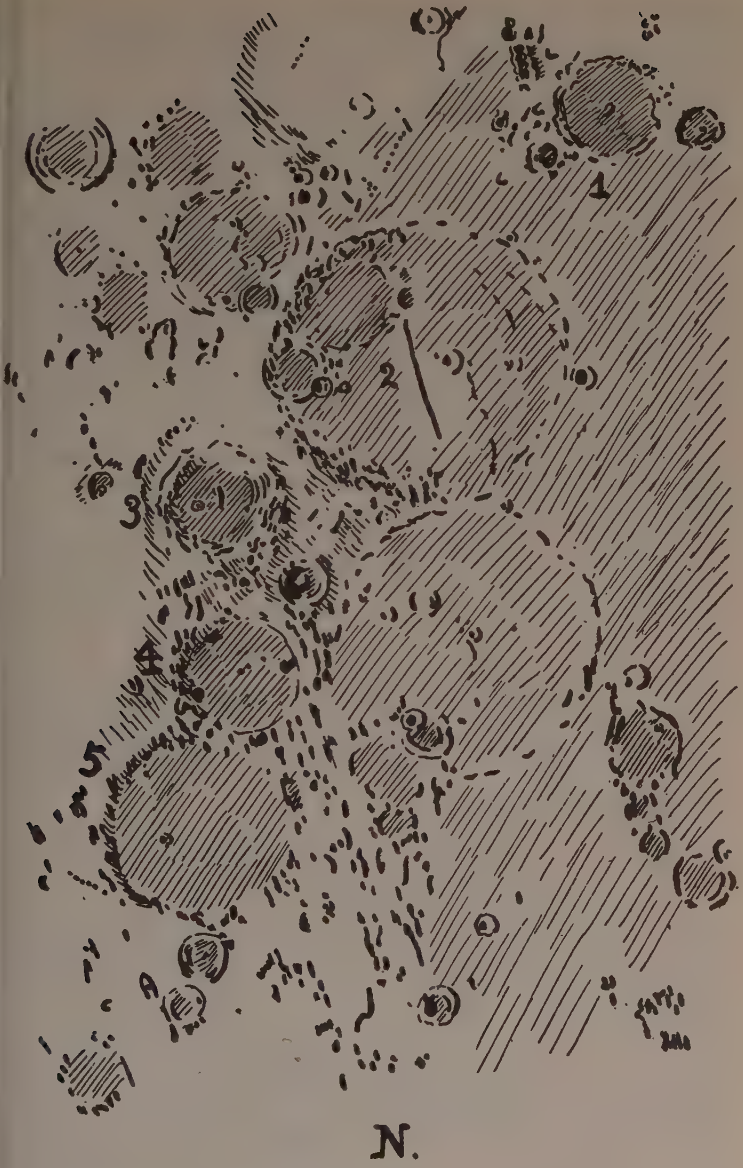

Fig. 2.—The Moon; portion of Third Quadrant. Sketch of the Mare Nubium, left, with (1) Pitatus; (2) Straight Wall; (3) Arzachel (with terraces); (4) Alphonsus (with three "gardens"); (5) Ptolemaeus with Hershel below.

Alphonsus is 83 miles in diameter, and is chiefly remarkable for the three sooty black spots round the edge, at the base of the circling cliffs. Pickering believed them to be due to vegetation.[1] The north-easterly "garden" certainly "grows" during the lunation, and apparently was not there formerly, for Neison, 1876, fails to record it, though mentioning the other two. The writer has noticed that these patches of "vegetation" are always associated with small volcanic vents, so it may be that in the absence of an appreciable atmosphere, some lowly form of plant life may take advantage of the gases given off from these spiracles to supply their vital energy. They would be some form of freshwater alga, such as grows upon the red tiles of a roof, or which tenders the bare granite hills in Angola a vivid black in the rainy season; Welwitsch also describes another form that covers the sandy valleys in the same region. In Australia "coorongite" or vegetable caoutchouc is due to the same plants, and the writer has found a red alga forming a similar elastic covering to the sand in the Kalahari.[2]

Arzachel is 65·5 miles across, and 14,000 feet deep, though the rim is only 6,000 feet above the surrounding plain. The successive terraces, both inside and out, are very well defined.

On the west of the above-mentioned three, there are two enormous torsion cylinders, 200 miles in diameter. They have not received any distinctive names because ordinarily they appear to merge into the plain of the Mare Nubium, without demarcation, but under suitable oblique illumination they are perfectly clear. They are not portions of an earlier topography overwhelmed by the lava floods that formed the sea, but have been rounded out of the substance of the moon after that effusion of molten rock had cooled down. Similar tops of cylinders are apparent all over the visible surface of the moon; they look like the dents made by a hammer head on soft wood.

In these five examples, there are all stages from the very first effort, when the cylinder is just formed, to Ptolemaeus, Alphonsus, and Arzachel, in the last of which a definite crater-ring with terraces is manifest; Albetragius, the deep ring on the west, between Alphonsus and Arzachel, is a still further development, when the chimney is much smaller, 26 miles across, while the walls tower 12,000 feet above the chasm. The central peak rises 7,000 feet above the floor.

The Straight Wall has an average height of 450 feet, and is 65 miles long. It lies parallel to the general grain of the country, as seen in the innumerable dykes in this region; in this matter, the fault is similar in nature to the swarm of dykes round Glencoe, or more especially, with the dolerite dykes round the Pilandsberg, which pierce the cylinder, and appear right in the centre, among the tuffs belonging to the volcano itself.

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[1] W. H. Pickering, *Annals of Harvard College Observatory*, also his *Photographic Atlas of the Moon*, 1904; W. H. M. Christie, *Monthly Notices, R. Astron. Soc.*, vol. lxxxi, 1921, pp. 451 and 490.

[2] *Causal Geology*, p. 82.

On the south-east of the cylinder in which lies the Straight Wall, there are two smaller, excentric ones, exhibiting thus a feature that is common in many of the lunar crater-rings, Catherina, for instance.

Torsion cylinders, either round, oblong, or elongated, may account for many of the pits and hollows of the earth's surface, where the evidence is obscured by soil and vegetation. The point in size at which the smallest cylinder stops, and the true explosion chimney begins, is not yet determinable. It seems certain that in the case of a gigantic crater, like the Pilandsberg or Ngorongoro, if the vent had been open from side to side, and the volcanic gases burst out in one cataclysmic blast, the whole earth would have been eviscerated. Krakatoa shook the earth, but what would have happened if the shock had been multiplied 1,200 times? Taking the diameter of the neck of Krakatoa as half a mile and Pilandsberg 18 miles, then the force of explosion would have been proportional to the areas as 1 to 1,296. When we find crater rings on the moon from 100 to 200 miles in diameter, and the force of the explosion represented in terms of Krakatoa as 160,000 and 640,000 times as violent, our satellite could not have stood it.

The Heavy Minerals of the Plutonic Rocks of the Channel Islands: 2. Guernsey, Sark, and Alderney.

By A. W. Groves, M.Sc., D.I.C., Research Student, Royal College of Science, London.

GUERNSEY.

IN a previous article in this magazine the heavy minerals of the plutonic rocks of Jersey were described, and it was shown that the mineralogical evidence confirmed the existence of granites of two ages, the "Older" and the "Newer" Granites. Of these the "Newer" Granite was intrusive into the gabbro and the resulting hybrid rocks were shown to yield a mixture of granite and gabbro suites of heavy minerals. Very marked contrasts to the Armorican granites of the West of England were pointed out. This work has now been extended to Guernsey and, by its means, correlation is effected between the plutonic rocks of these two islands separated by 25 miles of the English Channel.

The method of procedure has already been outlined. Specimens were collected from the following localities:—

DIFFERENTIATION SERIES OF NORTHERN HALF OF GUERNSEY.	Cobo Granite ("Older" Granite.)	Cobo Beach. Fort Hommet. Rocque de Guet Quarry, Albecq.
	Intermediate differentiates and hybrids.	Lancresse Common— (*a*) Sea cliff by quarry. (*b*) Top of quarry. (*c*) By Martello tower near quarry. Les Vardes. Two specimens.
	Gabbro plus quartz, etc.	Jouas Quarry, S. of Vale Church. Quarry near Bordeaux. Hougue Ricart, near St. Sampsons.
	Gabbro.	Quarry on S. side of St. Sampsons Harbour.
GNEISSOSE ROCKS OF SOUTHERN HALF OF GUERNSEY.	Granitic Gneiss.	Small Bay S. of Havelet Bay. Lane S.E. of Forest Church.
	Pea Stacks Gneiss.	W. of St. Martin's Point.
	Dioritic Gneiss.	Pleinmont. North of L'Erée.
	(L'Erée Type.)	L'Erée. Portelot.
	(Torteval Type.)	Near Rocquaine Castle.
	Dioritic Gneiss.	Castle Cornet, by the entrance.
	Aplite.	Intruded into gneiss at Castle Cornet.
	Quartz rock.	Jerbourg. Dyke, about 70 ft. thick.

"OLDER" GRANITE.

The "Older" Granite of Jersey is present as the granite intrusions of the N.W. and N. coasts of Guernsey, i.e. Cobo, Grand-Rocque, Les Vardes, Crève Coeur, and south of Fort Marchant, on Lancresse Common. No representative of the "Newer" Granite of Jersey has been found. Towards the margin of the granite mass contamination increases rapidly. The best uncontaminated "Older" Granite is that exposed along the whole length of Cobo Bay where it has a marked reddish aspect. This reddish colour is again conspicuous in the middle of the outcrop on the Common north of Lancresse. The colour of the rock is due to the reddening of the felspars by iron oxide: but this is not due to local pneumatolysis, for the whole mass—where not strongly contaminated by more basic material—is reddened, as are also the contemporary Gorey and Fort Regent masses in Jersey. The phenomenon appears to be due to autopneumatolysis at a very late stage of crystallization and is a characteristic of the "Older" Granite. In this connexion it is of interest to point out that the Granite Gneiss of the Lizard is, for the most part, similarly reddened.

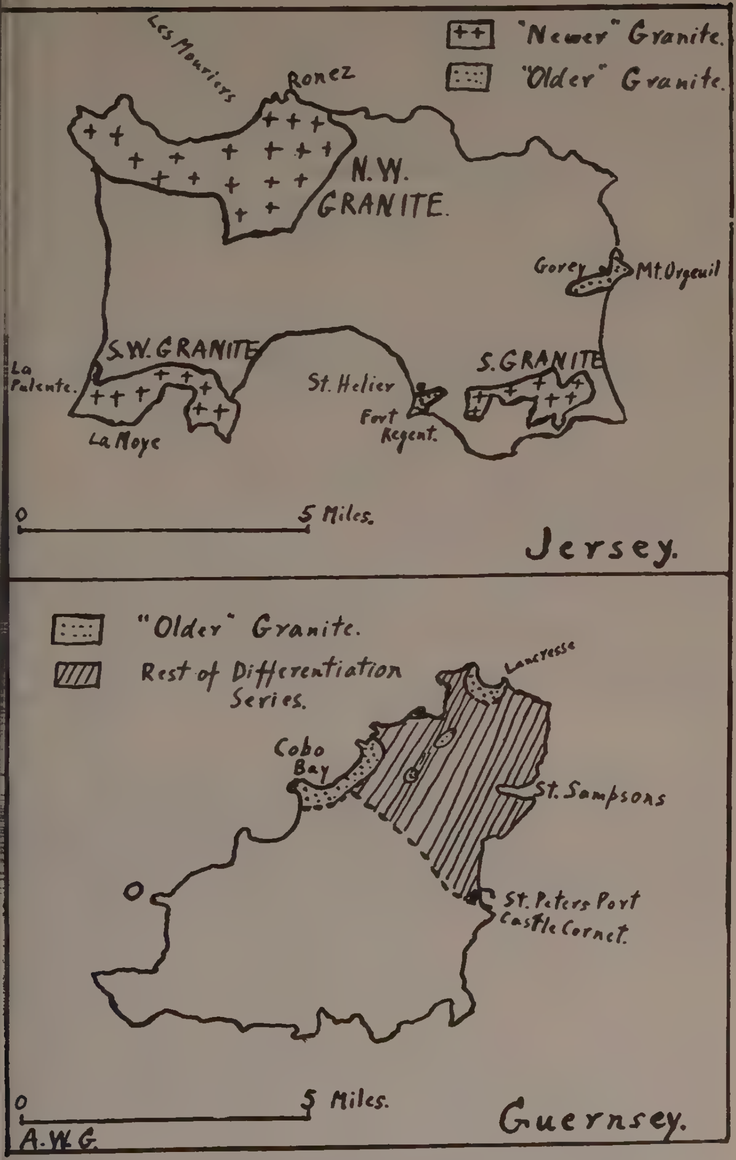

Fig. 1.—Sketch-maps showing distribution of "Newer" and "Older" Granites in Jersey and Guernsey.

The heavy mineral suite afforded by three specimens collected around Cobo Bay is identical in almost every respect with those of the Gorey and Fort Regent outcrops in Jersey. The closeness of the similarity is indeed remarkable. If, further, the index figure (1)[1] for these specimens and those of Gorey and Fort Regent in Jersey be compared it will be seen that, with the exception of the Rocque de Guet specimen, it is below unity in each case. The slightly higher figure for Rocque de Guet is because this specimen is fresher and its biotite is not chloritized to any extent, while the other specimens are all decomposed, fresh specimens being difficult to obtain.

COMPARISON OF THE COBO GRANITE WITH THE "OLDER" GRANITE OF JERSEY.

Heavy minerals in Jersey "Older" Granite :—	Heavy minerals in Guernsey (Cobo) Granite :—
Zircon, Apatite, Biotite, Chlorite, Magnetite, Haematite, Sphene (rare).	Zircon, Apatite, Biotite, Chlorite, Magnetite, Haematite.
Average Index Figure, ·63.	Average Index Figure, ·96.
Zircons : Brown or yellow. Some zoning. Some slightly larger colourless ones with irregularly arranged inclusions, and having two pyramids. Corroded.	Zircons : Ditto. Corrosion common, but less severe.
Average length of zircons, ·05–·1 mm.	Average length of zircons, ·05–·15 mm.
Apatite : Crystal faces rarely seen. No inclusions.	Apatite : Crystal faces rarely seen. No inclusions.
Magnetite : Occurs in good octahedra.	Magnetite : Occurs in good octahedra.

THE GABBRO.

The heavy minerals found in the hornblende-gabbro occurring along the east coast around St. Sampsons Harbour are enumerated in the main table and, with the exception of barkevikite and titanaugite, they compare closely with those of the gabbro at Ronez. Correlation between these two gabbros must not be made, however, for the following reasons. Field evidence shows that the "Older" Granite of Jersey is prior in age to the lavas. It has been shown by Parkinson, and Bonney and Hill (2) that the Guernsey gabbro was the first intrusion of a series of rocks of which the last is here shown to have been the Cobo granite (which is correlated with the "Older" Granite of Jersey). The gabbro at Ronez is intruded into rhyolite and must therefore be younger than the Guernsey gabbro. Thus the statement in the previous paper on Jersey that the Ronez gabbro is intermediate in age between the "Newer" and "Older" Granite still holds, and the Guernsey gabbro must be regarded as the oldest of the non-foliated plutonic masses of Jersey and

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[1] Figures in parentheses refer to Bibliography at end of paper.

Guernsey inasmuch as it was the first member of the Differentiation Series to be intruded.

In passing it may be mentioned that the Guernsey gabbro of coarse texture occurring at St. Sampsons cannot be distinguished, in the hand specimen, from much of the normal Lizard gabbro.

In the very coarse-grained and most basic variety of gabbro of St. Sampsons no zircon has been observed. This is not altogether strange inasmuch as the quantity of zircon is always much less in gabbroid than in granitic rocks and this being the most basic type dealt with, would be expected to contain the least quantity of zircon. Zircon was not found in the specimens of the Lizard gabbro, and it is scarce in the olivine-gabbro of Wolf Cave in Jersey. There appears to be some evidence to show that in the Differentiation Series of Guernsey the amount of zircon increased as differentiation proceeded, in a manner similar to the progressive increase in tourmaline in the successive intrusions of the Dartmoor granite (3).

THE MIXED ROCKS OF THE NORTH OF GUERNSEY.

As in the case of the hybrid rocks of Jersey it has been deemed advisable to include a petrographical description of each of the specimens in order that the exact nature of the material used may be appreciated. It will be seen that the heavy mineral evidence agrees perfectly with the petrographical and field evidence. In cases where there has been admixture of granitic and basic material, zircons of both the Cobo granite type and the gabbro type occur. The presence of the Cobo granite zircons in the dioritic rocks is conclusive evidence that the Cobo granite is also a member of the Differentiation Series. Dr. J. Parkinson appears to have thought this improbable (4). Moreover, actual granitic variations of reddish colour and containing Cobo type zircons occur on Lancresse Common, and at the southern end of the Fort Marchant promontory in the midst of the " diorites ". The following petrographical notes show that the " diorites " are of three kinds : (*a*) true diorites and tonalites, (*b*) rocks which would have been diorites but which at a late stage of consolidation were intruded and soused by siliceous or granitic fluids, (*c*) rocks which would have been gabbros but which during consolidation were permeated with acid material.

(*a*) *Fort Marchant Promontory. Sea Cliff at Side of Quarry.*

Shows slight intrusion foliation. Abundant quartz showing undulose extinction and further a definite fracturing and recementing n one direction. The quartz forming the recementing material may or may not be in optical continuity with the original. The elspar is turbid with kaolinization resulting in a reddening of the rock but determination of species is possible. Occasionally the plagioclase is shown by its twin lamellae to be bent. The maximum symmetrical extinction angle is 12°, corresponding to an acid andesine. There is much microperthitic intergrowth of orthoclase and another felspar (as in the Cobo granite) and orthoclase, being in excess of plagioclase, this is a granite.

This rock appears to have been intruded in a plastic condition resulting in the interstitial mortar structure.

(*b*) *Les Vardes.*

Biotite and hornblende in a groundmass of plagioclase and quartz. There is a considerable amount of quartz occurring in large patches and showing undulose extinction. The quartz is almost equal in amount to felspar and included in it are numerous idiomorphic crystals of apatite measuring up to a millimetre long and ·15 mm. thick. A number of zoned plagioclases occur, the inner zone being always kaolinized and evidently more basic than the surrounding zone. The plagioclase is of two kinds, one with a maximum symmetrical extinction angle of 7°, and the other 24°, corresponding to a basic oligoclase and a basic andesine (American classification).

The green hornblende has a decided tendency to be converted into biotite, patches of biotite of vague outline occurring in the midst of the hornblende. Biotite and quartz appear to have been the last minerals to crystallize. There is also accessory idiomorphic magnetite.

The term quartz-mica-diorite applied to this rock by Dr. J. Parkinson (5) is more or less justified, but the amount of quartz present is so considerable that it would appear that the magma of this rock was, in the early stages of consolidation, a true diorite or tonalite and that as crystallization proceeded additional quantities of free silica were introduced, probably from the neighbouring granite.

(*c*) *Fort Marchant Promontory, by Martello Tower.*

Biotite and hornblende in a matrix of plagioclase and quartz. The form of the quartz is of interest, as it occurs in rather small grain granular mosaics forming a groundmass to the much larger and basic plagioclase crystals. The large felspars measure up to 3 or 4 mm. in length and their well-marked lamellar twinning frequently shows bending and fracturing particularly towards the ends. The plagioclase varies from basic andesine to acid labradorite. Biotite and green hornblende occur in the same manner as at Les Vardes.

The occurrence of so much quartz along with felspar as basic as labradorite shows, even more clearly than at Les Vardes, that the rock was subjected at a stage later than the consolidation of the basic felspar to the introduction of acid material which formed a finer grained groundmass. The introduction of acid material probably took place while the original constituents were scarcely consolidated and this would account for the bending and fracturing and slight corrosion of the original felspars.

Included in the rock are finer grained segregation patches, consisting of andesine accompanied by more plentiful hornblende and biotite, as noted by Parkinson (6).

(*d*) *Jouas Quarry S. of Vale Mill.*

Hornblende, biotite, and some augite in a groundmass of plagioclase containing numerous quartz patches constitutes the bulk of the rock. The plagioclase occurs in rather larger zoned crystals and fresher unzoned crystals, some showing rather broad twin lamellae and the majority rather narrow twin lamellae. There is a strong suggestion that the earlier and larger felspars were more basic than those which crystallized out later. The maximum symmetrical extinction angle shown by the later plagioclase is 22°—andesine. The quartz appears in irregular patches, some of considerable size, running in and out between the fairly idiomorphic felspars, evidently the last mineral to crystallize, but the way in which it appears to have come in and forced the felspars apart to make room for it suggests that it is an acid permeation introduced when the rock had very nearly consolidated.

In addition to the green hornblende and biotite there is some greenish brown augite seen in the process of being converted into hornblende. Occasional crystals of sphene occur both in the augite and hornblende, together with some magnetite. Much of the hornblende is definitely primary and shows excellent twinning parallel to (100).

This rock is slightly more basic than that of Les Vardes and this is reflected in the index figure. The rock would originally have been a rather basic diorite, but now approximates to a tonalite.

(*e*) *Quarry near Bordeaux.*

Numerous large phenocrysts of a decomposed felspar, which was evidently a plagioclase as is shown by the paragonitization, occur up to 3 or 4 mm. long. The phenocrysts are bordered by a translucent secondary felspar of lower R.I. than the other felspars, which is possibly albite. In some cases epidote has been formed in small quantity inside the altered plagioclase. The later formed felspar is all andesine. A considerable amount of quartz is present in the groundmass.

The ferromagnesian constituents are hornblende and biotite with a small quantity of yellowish-brown augite.

Accessory apatite, pyrite, and magnetite occur, of which the pyrite is beautifully idiomorphic. The rock now approximates in composition to a tonalite and is very similar to that from Jouas.

f) *Hougue Ricart, near St. Sampsons.*

Abundant hornblende pleochroic from straw-yellow to a rather bluish green is the dominant mineral. There is also much biotite of a greenish colour, changing over to chlorite, as well as some crystals of hornblende bordered by green biotite. Evidently there was a marked tendency for the hornblende to give way to biotite, as noted both by Parkinson and Bonney and Hill (7). The amphibole is no doubt in part derived from pyroxene and in part primary.

The felspar is completely altered to a turbid low-polarizing mass—saussuritization probably, since small quantities of secondary albite have been formed. In other cases the felspar crystals have been almost entirely replaced by a colourless, but bright polarizing epidote. Numerous patches of blebs of quartz occur and are evidently of later origin in most cases, although an occasional larger quartz grain may be primary. In this connexion it is interesting to note what Parkinson says about a similar rock at Hommet Bennest: "Small patches of quartz and a translucent felspar are found here and there. Hornblende bordering these patches assumes the form of an actinolitic fringe. Comparison with other slides suggests that these patches are the early stages of a permeation by a more acid magma (8)." (The actinolitic fringe does not happen to occur in any of my slides.) The spongy quartz, together with the equally abundant epidote, are present in too large quantity to have been derived from the breakdown of former minerals. They must be secondary in the sense that they have been introduced after consolidation and are probably derived from the more acid members of the Differentiation Series. The solutions probably aided in the breakdown and amphibolization of the pyroxene.

There is also accessory idiomorphic pyrite, ilmenite altering to leucoxene, and some apatite. The rock was originally a gabbro but is now in the condition of an epidiorite.

(*g*) *The Hornblende-Gabbro of St. Sampsons.*

This has already been described by Bonney and Hill and Parkinson. It is a hornblende-labradorite rock with the former mineral more or less completely replacing augite, and is cut by somewhat later dykes of two types.

The petrographical evidence afforded by these thin sections indicates a gradation from granite to gabbro with, in the more basic rocks, a subsequent permeation by acid material derived from the granite. This is a case of differentiation of a magma whereby successive intrusions were increasingly acid and followed one another without any great pause. The crystallization of the gabbro was practically complete before the incoming of the siliceous solutions. In the case of some of the diorites crystallization was somewhat less complete when there was invasion by granitic material. Then intrusion of granite formed the final stage.

The Southern Half of Guernsey.

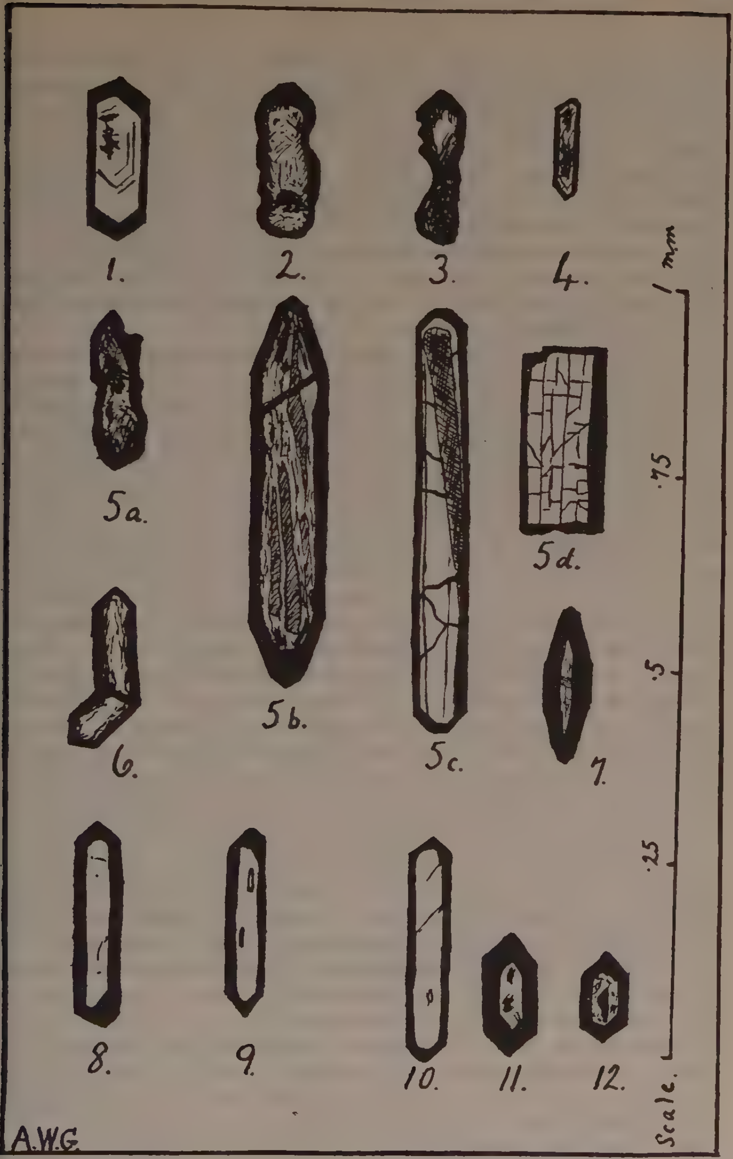
The rocks so far dealt with all occur in the northern part of the island, which is entirely occupied by what is generally known as

Table Showing Distribution of the Heavy Minerals.

Locality.	No. of Specimens.	Zircon.	(Gabbro Type.)	Apatite.	Biotite.	Muscovite.	Hornblende.	(Bluish-green.)	Barkevikite.	Actinolite.	Sphene.	Epidote.	Clinozoisite.	Zoisite.	Allanite.	Chlorite.	Fluor.	Magnetite.	Ilmenite.	Leucoxene.	Haematite.	Limonite.	Pyrite.	Molybdenite.	Topaz.	Sillimanite.	Rutile.	Anatase.	Olivine.	Titan Augite.	Leucaugite.	Augite.	Hypersthene.	Galena.	Description of Specimens.	% of heavy min'ls = Index figure.
Ronez	1	4	–	4	5	–	5	–	–	–	4	3	3	–	–	3	5	4	–	–	–	–	4	2	–	3	–	–	–	–	–	–	–	–	" Newer " Granite.	8·2
Mont Mado	3	4	–	4	5	–	5	–	–	–	4	3	3	–	–	3	5	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	3·8
Les Mouriers . .	1	4	–	4	5	–	5	–	–	–	3	–	–	–	–	3	–	3	3	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	16·8
La Moye . . .	2	4	–	4	5	–	5	–	–	–	4	3	3	–	–	3	5	4	3	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	,, ,,	8·9
La Pulente	1	4	–	4	5	–	5	–	–	–	3	3	–	–	–	3	5	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	5·3
St. Aubin . . .	2	4	–	4	5	–	5	–	–	–	3	–	–	–	–	3	–	3	3	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	9·1
Pontac . . .	1	4	–	4	5	–	–	–	–	–	4	5	4	4	–	5	–	3	3	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	,, ,,	6·7
Longueville	1	4	–	5	5	–	3	–	–	–	4	3	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	19·7
The Hermitage . .	1	4	+	4	5	–	5	–	–	–	3	5	3	–	–	5	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Hybrid.	48
St. Clements. . .	1	4	+	4	5	–	5	–	–	–	5	5	3	3	–	5	–	4	3	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	,,	51
Battery, Ronez . .	1	4	+	4	5	–	5	–	5	–	5	4	1	3	–	5	–	3	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	Gabbro.	53
Ronez	1	3	+	4	4	–	4	–	4	–	3	4	–	–	–	4	–	3	3	–	–	–	5	–	–	–	1	–	–	3	–	–	–	–	Gabbro Pegmatite.	29·5
Wolf Cave	1	1	+	3	5	–	5	–	4	–	4	4	–	5	–	5	–	3	3	–	–	–	–	–	–	–	1	–	5	5	–	–	–	–	Olivine Gabbro.	69·8
Gorey	2	3	–	–	3	–	–	–	–	–	1	–	–	–	–	3	–	4	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	" Older " Granite.	0·2
Fort Regent . .	3	3	–	2	–	–	–	–	–	–	–	–	–	–	–	3	–	4	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	0·9
Bathing Pool . .	1	3	–	2	–	–	–	–	–	–	–	–	–	–	–	3	–	3	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	0·8
Pen Voose . . .	2	3	–	4	3	–	–	–	–	–	–	–	–	–	–	3	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Granite Gneiss.	0·39
Kennack Cove . .	2	–	–	–	–	–	2	–	–	–	–	2	–	–	–	–	–	4	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	0·31
Goonhilly Down . .	2	–	–	4	5	5	2	–	–	–	2	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	0·68
Crousa Downs . .	2	–	–	5	–	–	5	–	–	–	3	5	–	–	–	–	–	3	5	3	–	–	–	–	–	–	–	–	5	–	–	–	–	–	Gabbro.	51·3
Fort Hommet	1	3	–	1	3	–	–	–	–	–	–	–	–	–	–	2	–	4	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	" Older " Granite.	0·1
Cobo . .	1	3	–	1	4	–	–	–	–	–	–	–	–	–	–	2	–	4	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	0·8
Rocque de Guet	1	3	–	3	4	–	–	–	–	–	–	–	–	–	–	2	–	4	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	2·0
Fort Marchant	1	4	–	4	5	–	–	–	–	–	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	4·0
Lancresse Common	1	3	–	3	–	–	–	–	–	–	–	–	–	–	–	2	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	4·5
Martello Tr. ,,	1	4	+	4	5	–	5	–	–	–	4	–	–	–	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Hybrid Dioritic.	23·5
Les Vardes .	1	4	+	4	5	–	5	–	–	–	4	3	–	–	–	4	–	4	–	2	–	–	4	–	–	–	–	–	–	–	–	–	–	–	,, ,,	27·1
Bordeaux .	1	4	+	4	5	–	5	–	–	–	4	–	–	–	–	–	–	4	–	–	–	–	5	–	–	–	–	–	–	–	–	2	–	–	,, ,,	30·1
Jouas Quarry	1	3	+	4	5	–	5	–	–	–	4	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	,, ,,	33·6
Hougue Ricart	1	2	+	3	–	–	5	–	–	–	4	4	–	–	–	4	–	–	3	2	–	–	4	–	–	–	–	–	–	–	–	–	–	2	Gabbro. (Epidiorite.)	38·5
St. Sampsons	1	–	+	5	5	–	5	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Gabbro.	48·8
S. Havelet Bay . .	1	3	–	4	–	4	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Granitic Gneiss.	3·0
S.E. Forest Church .	1	4	–	4	2	4	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	3·4
Near Pea Stacks . .	1	4	–	4	–	–	–	–	–	–	–	–	–	–	4	–	–	–	–	–	2	–	4	–	–	–	–	–	–	–	–	–	–	–	Pea Stacks Gneiss.	·7
Pleinmont . . .	1	3	–	4	4	4	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Dioritic Gneiss.	11·6
N. of L'Erée. . .	1	3	–	4	5	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	28·1
L'Erée . . .	1	4	–	4	4	4	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	4·7
Portelet . . .	1	3	–	4	4	–	–	2	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	1·0
Near Rocquaine Cas. .	1	3	–	4	5	–	–	5	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,, (Torteval Type)	10·0
Castle Cornet . .	1	5	–	3	–	–	–	5	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	33·3
,, ,, . .	1	3	–	1	3	–	–	–	–	–	–	–	–	–	2	3	–	3	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	Aplite.	1·0
Jerbourg . .	1	–	–	–	1	–	1	–	–	–	–	2	–	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	Quartz Dyke.	Trace
North Tourgis . .	1	4	–	4	5	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	" Newer " Granite (?)	15·7
Bibette . . .	1	4	–	4	5	–	5	–	–	–	5	2	2	2	–	4	–	3	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	,, ,,	17·1
S. Alderney	1	3	–	3	4	–	–	–	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	" Older " Granite (?).	·9
,, ...	1	4	–	3	3	–	–	–	–	–	–	–	–	–	–	3	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Granite Porphyry.	1·8
La Quoire . . .	1	2	–	4	5	–	5	–	–	–	3	–	–	–	–	2	–	5	–	–	–	–	–	–	–	–	–	–	–	–	2	–	5	–	Gabbro.	50·0
Roselle Bay	1	4	–	5	5	–	–	–	–	–	5	–	–	–	–	3	–	3	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	Tonalite.	11·1
,, ...	1	2	–	5	5	–	5	–	–	–	–	–	–	–	–	–	–	5	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	Gabbro.	42·1
,, ...	1	–	–	5	–	–	5	–	–	5	–	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Amphibolite.	81·8
,, ...	1	1	–	–	–	–	–	–	–	5	–	–	–	–	–	5	–	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	,,	100
Sark	2	4	–	5	5	–	5	–	–	3	5	–	3	3	–	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	" Newer " Granite.	22·6

Differentiation Series. Increase in Basicity.

Explanation of Symbols: 5 = Abundant; 4 = Very Common; 3 = Less Common; 2 = Scarce; 1 = Rare; + Denotes the presence of zircons of Gabbro Type.



IG. 2.—Some typical zircons drawn to scale. "Older" Granite and Differentiation Series:—(1) Cobo; (2) Cobo (corroded); (3) Lancresse (corroded); (4) Lancresse; (5) Diorite, Les Vardes: (*a*) granite type (corroded), (*b*) gabbro type (greyish-brown), (*c*) gabbro type with brown inclusion of xenotime, (*d*) gabbro type showing system of cleavage cracks parallel to (110), (001), and (111). Coloured rose-pink; (11) and (12) Southern Alderney. "Newer Granite": (8) Sark, Dioritic Gneiss; (9) Bibette, Alderney; (10) Tourgis, Alderney. Gneissic Rocks of South Guernsey: (6) Geniculate twin, L'Erée type of Dioritic Gneiss, L'Erée; (7) Granitic Gneiss, south of Havelet Bay.

the Differentiation Series. In the southern half of the island we have a series of orthogneisses together with a few small areas of schists of sedimentary origin, everything in the island generally being considered to be of Pre-Cambrian age with the possible exception of some minor intrusions. The geology of Southern Guernsey has recently been described by D. J. Farquharson (9). He has shown that the gneiss of Bonney and Hill is mainly granitic gneiss but that there are also several types of dioritic gneiss including one showing augen structure (Torteval Type). The specimens examined from southern Guernsey embrace all the plutonic types described by Farquharson.

There is a general similarity between the residues, and the zircons are different from those met with elsewhere in the Channel Islands. They are generally colourless but are more rounded in the principal zone due to the development of a second prism. The sharp terminations due to the steeper pyramid (311) terminated by a small development of the unit pyramid (111) is characteristic. Some examples of geniculate twinning have been observed, and one of these is illustrated in the drawings of Fig. 2. This is the only group of rocks in the islands containing muscovite.

The one residue which shows some differences from the others is the Pea Stacks Gneiss and this is chiefly due to the development of allanite (noted by Farquharson) and bright yellow zircons. The occurrence of allanite in the aplite intruded into the gneiss of Castle Cornet seems to indicate that these aplites are genetically connected with the Pea Stacks Gneiss. The allanite does not occur in definite crystal outlines. Farquharson describes its appearance in thin section as (10) " a dull red mineral, occurring in small clusters or masses of conchoidal grains, or as thin plates, feebly pleochroic in blood-red to dark amber brown tints and with a high R.I., may probably be identified as allanite ". In grains the pleochroism is from amber to foxy-red and in occurrence is quite common. Under the high power the colour is seen to be patchily distributed. Other grains are cloudy in patches, apparently due to alteration. The B.R. is moderately high but obscured by the body colour. Grains are frequently bordered by a colourless mineral of extremely low B.R. and which is probably clinozoisite.

The zircons of the Pea Stacks Gneiss are all rounded in a manner resembling those of a sediment. This apparently is due to the movements resulting in the gneissic structure, which is very severe in this case.

The Castle Cornet Gneiss has a much higher index figure corresponding to a rather basic diorite. Its hornblende is of a distinctly bluish-green as is also the case with the hornblende of the Torteval Type of Dioritic Gneiss. The zircons are rather large and inclined to be coloured. The occurrence of anatase in this rock is the only known occurrence of the mineral in the Channel Islands but it is very doubtful if it ever contributed materially to the sedimentary strata as it is so rare, only about half a dozen grains being noted. It occurs in fairly large grains appearing almost black and opaque but which clear up to a rich indigo colour when the condenser is used. The R.I. is extremely high as is also the B.R. The dispersion is so strong that a proper interference figure is unobtainable. It exhibits conchoidal fracture and all the grains are unfortunately broken so that the form and habit cannot be observed. As there is an aplite dyke a few yards from where the specimen was taken it would seem probable that the anatase was formed as a result of solutions emanating from the aplite. On the other hand no anatase was found in the aplite and so it is concluded that the hot solutions from the aplite set free some TiO_2 from the ferromagnesian minerals of the gneiss.

The index figure for the specimen from Portelet, although this is on the outcrop of the L'Erée Gneiss (dioritic) on Farquharson's map (11) is so low that it cannot be dioritic but must be granitic in composition. It would thus appear that the distribution of the granitic and dioritic gneisses is probably more complicated than would appear from this map. Indeed, Mr. Farquharson admits that differentiation between the various types of gneisses in the field is most difficult.

The heavy residues of these gneissic rocks are dissimilar to those of all the other rocks of the Channel Islands which is in agreement with their being the oldest plutonic rocks of the islands.

The Man o' War Gneiss of the Old Lizard Head and the skerries to the south of it, was originally comparable to tonalite (12), and it seems possible that it is the equivalent of the Dioritic Gneiss of Guernsey, much of which also approximated to a tonalite in composition.

SARK.

The base of the island is everywhere seen to consist of dioritic gneiss, tonalite, and granite, the various types passing gradually into one another. In his paper on the "Petrology of Sark" (13) Mr. Wooldridge gives both petrographical and field evidence showing that this mass is intrusive into hornblendites, amphibolites, aplites, hornblende-schists, and mica-schists, and that there has been considerable assimilation by the magma, which was essentially granitic, but which as a result has given place to hybrids approximating to tonalite and diorite in composition.

The heavy residue yielded by specimens of the Dioritic Gneiss is exceptionally rich in sphene of two kinds, brown, and almost colourless. During the crushing of the rock several reddish-brown perfect crystals of sphene measuring 3 or 4 millimetres were noted. The average index figure for two specimens was 22·6, and this agrees with a rock having a dioritic composition. The zircons range from ·1 to ·4 mm. in length and average about ·3 mm. The majority are colourless and capped by the unit pyramid, and often contain small inclusions. These are of "Newer" Granite type; but there are in addition other zircons resembling neither those of the "Newer" nor "Older" Granite, and these are presumed to be derived from the large quantities of basic rock which have been assimilated. Some of the hornblende is of the bright green actinolitic variety noted by Wooldridge (14) and ascribed by him to reheating of the country rock as it became absorbed, more or less mechanically, in the invading magma. There is thus every reason to suppose that the anomalous zircons were similarly derived, more or less mechanically and without refusion, from the invaded rocks. The presence of zoisite and clinozoisite in the Dioritic Gneiss, noted by Wooldridge (15) is also strongly in favour of the view that this is a representative of the "Newer" Granitc, although its character has been much changed by extensive assimilation. The similar rocks on the neighbouring island of Brechou are thus probably also representatives of the "Newer" Granite.

ALDERNEY.

The igneous geology of Alderney is very complicated owing to the numerous rock types, representing a number of different intrusions of various ages, accompanied by differentiation, and probably assimilation. There has been considerable subsequent faulting and the injection of many minor intrusions, but the worst difficulty is the inaccessibility of many of the cliffs, which as the Rev. E. Hill pointed out are swept by some of the strongest tides in Europe, coupled with the fact that about two-thirds of the plutonic solid geology is obscured by what have been shown by Hill and Plymen to be Cambrian sediments and a sill-like mass of granite porphyry.

Its geology has been investigated by the Rev. E. Hill (16) and more recently by Dr. Plymen (17). A detailed study of its petrology has yet to be undertaken, and the examination of the few thin sections here described shows considerable inaccuracy in the field petrological terms which have hitherto been used.

Owing to the unsatisfactory state of our knowledge of the petrology of Alderney I cannot do more than make the following observations as the result of my examination of the heavy minerals of a collection of specimens which, though not large, is representative of the main types. As the distribution of the rock types is not accurately known my remarks must lack precision.

The granite mass forming Bibette Head and Tourgis Point yields a residue similar in many respects to that of the "Newer" Granite of Jersey. In support of this statement is the high index figure and the presence of clinozoisite.

A specimen of granite from the south of Alderney is totally different and appears to belong to the "Older" Granite. The index figure agrees perfectly with this observation. The Granite Porphyry of Southern Alderney seems to be related to this granite.

The amphibolites of Roselle Bay are probably derived from gabbro, but in their altered state correlation is not possible.

Certain of the diorites of Roselle Bay and La Quoire yield residues similar to the diorites of Northern Guernsey.

PETROGRAPHICAL NOTES ON THE SPECIMENS EXAMINED FROM ALDERNEY.

Amphibolite, Roselle Bay. Index Figure 81·8.

In the hand specimen this rock is almost black and has a very coarse texture resembling that of a gabbro. It is friable and required hardening with a mixture of cresyllic acid and formaldehyde solution before a thin section could be cut.

In thin section it is seen that the bulk of the rock is composed of large crystals of dark brown hornblende almost of basaltic type. Here and there the hornblende passes at its margin into a very pale green amphibole, a kind of actinolite similar to that in the next specimen. Other hornblende crystals pass at their ends into bundles of blade-like actinolite crystals and there is also much interstitial acicular actinolite. Numerous patches occur of what appears to be a secondary felspar but crowded with small rounded granules of vermiculite. There is also some zoisite together with a little interstitial basic plagioclase. Minute grains of magnetite occur throughout the mass.

It is suggested that there has been a transfer of some lime from the lime-soda felspar to the hornblende with the production of actinolite, accompanied by the loss of some alumina and iron which has been used in the formation of some of the other secondary minerals. The amphibolite has resulted from the dynamic metamorphism of a basic rock, probably a gabbro, the texture of which has been largely preserved.

Amphibolite, Roselle Bay. Index Figure 100.

An interlocking mass of blade-like crystals of actinolite, grass-green in the hand specimen but practically colourless in thin section, and of moderately coarse texture. Patches of green chlorite occur here and there and an occasional patch of biotite, sometimes in process of chloritization. Minute idiomorphic crystals of magnetite occur throughout the rock. No foliation. In hand specimen shows slickensliding and evidently formed in a crush zone from a basic rock. Occasionally there is some indication of uralitization of former pyroxene. Strip twinning of the amphibole is common.

The formation of actinolite from hornblende at expense of basic plagioclase has in this case proceeded to the limit so that we have a remarkable example of a rock containing no minerals less than 2·8 in density. The passing of the crushed rock through bromoform, if carried out with care, is a good test for the presence of leucocratic minerals in these very basic rocks where the felspar or quartz, if any, might escape being caught in a thin section.

Roselle Bay. Index Figure 42·1.

Hornblende and biotite in a coarse-grained groundmass of decomposed basic plagioclase, constituting either a gabbro or basic diorite. All the interstices between the plagioclase crystals are occupied by quartz which as a result displays peculiar geometric forms. Numbers of these, which may be isolated in the thin section, are seen to be in optical continuity, showing that the quartz is occupying a most complicated cavity like the air cavities in a bath sponge.

The presence of so much quartz in such an otherwise basic rock is almost incompatible. The quartz must have been introduced, probably under pressure, at a very late stage of cooling. Similar phenomena have already been described in this paper from Jersey and Guernsey.

La Quoire. Index Figure 50.

Green hornblende, hypersthene, biotite, and magnetite are set in a coarsely intersertal groundmass of labradorite with some larger idiomorphic crystals of basic plagioclase in addition.

The rock is a rather fine-grained gabbro and has previously been called a diorite. Its index figure of 50, however, shows conclusively that it is too basic for a diorite. Its structure has a distinctly doleritic tendency and it would probably be called a dolerite by many petrographers were it not for the occurrence of larger porphyritic plagioclases in addition.

AGE OF THE CHANNEL ISLANDS GRANITES.

The relative ages of the granites are shown by the field evidence of previous investigators to be :—

"Newer" Granite.
"Older" Granite.
Gneisses of Southern Guernsey.

The heavy minerals of the "Older" Granite have been here shown to closely correspond with those of the Granite Gneiss of the Lizard, which is generally considered to be Pre-Cambrian. Accordingly a Pre-Cambrian age is assigned to both the "Older" Granite and the gneisses of Southern Guernsey. A considerable period of time must have elapsed after the formation of the gneisses of Southern Guernsey and before the intrusion of the Differentiation Series and "Older" Granite, for the former have suffered from earth movements while the latter are little disturbed. The gneisses thus evidently belong to an older division of the Pre-Cambrian than the "Older" Granite and Differentiation Series.

The "Newer" Granite has been suggested, in Jersey by Dr. Wells and what is probably "Newer" Granite in Sark by Mr. Wooldridge, to be possibly of Armorican age. Against this is the mineralogical evidence given in the first part of the paper. The fact that probably both "Newer" and "Older" Granites are present in Alderney is of the utmost importance, for there the whole igneous complex is unconformably overlain by early Cambrian sediments as fully described by Dr. Plymen (18). Thus there does not appear to be much doubt that the "Newer" Granite is Pre-Cambrian also.

The absence of any means of correlating the various plutonic rocks except by their macroscopic and microscopic appearance (and chemical analyses which, however, have never been used for the plutonic rocks in the Channel Islands) and the previously recognized fact that several types of plutonic rocks were involved in the complex has previously precluded precise correlation of the rocks of Alderney with those of the other Channel Islands and consequently prevented the full interpretation of the field evidence.

CONCLUSIONS CONCERNING THE METHOD OF CORRELATION.

The method of correlating plutonic outcrops by their accessory minerals has thus worked very satisfactorily over the entire area of the Channel Islands, although it evidently works best with the acid igneous rocks. There doubtless exist many similar cases where an igneous area has been dissected by the sea, and possibly by continental fragmentation, or where just the tops of the igneous cupolas of a plutonic mass are projecting from a sedimentary cover, and where correlation of plutonic rocks may be most expeditiously carried out by this means. In the Channel Islands the problem has been complicated by the existence of granites and diorites of several ages but this has only demonstrated to a greater degree the value of the method. The distance from the north of Alderney to the south of Jersey is about 40 miles. It remains to be seen whether the method is not applicable over even wider areas. The method certainly demands recognition.

There are certain wider problems to which it might be applied. There is the notable case of the Scottish granites regarding some of which it is not known whether they belong to the "Newer" or "Older" Granites.

The method is quicker than that of chemical analysis and has the added advantage that knowledge is gained not only of the names of the minor constituents but also of their crystallization history. Of the minerals to be used for correlation zircon is by far the most important since it is almost always present and it is scarcely damaged by the crushing. Its colour, habit or habits and crystal forms, together with micrometric measurements of the size, should be noted. These measurements may be of considerable use in correlation. Finally, notice should be taken of small but persistent peculiarities as regards inclusions, etc. The character of the apatite and its inclusions, if any, comes next in importance. Generally one or more minerals will be found to be characteristic of a granite and these minerals then become of paramount importance in correlation. In every case the heavy residue obtained should be weighed and the index figure obtained. It will be found that a granite has a definite and usually restricted range for its index figure. A sudden rise is always due to a sudden increase in the amount of the ferromagnesian minerals, for the proportion of zircon and apatite is always fairly steady, and such a rise generally indicates contamination of the granite by more basic material. Correlation must be based not on one character but on an unbiassed consideration of them all.

The importance of the index figure must not be lost sight of In the Channel Islands a determination of the index figure is almost without exception sufficient to show whether a specimen belongs to the "Newer" or "Older" Granite, the index figure for the former being less than unity and for the latter 5–15 or more according to the degree of assimilation. While the figures for granite are elastic, figures between about 10 and 20 indicate assimilation. Figures greater than 20 correspond to diorites and the line between diorites and gabbros can be taken somewhere around 35–40. In general the index figure increases with increase of basicity because the ferromagnesian minerals preponderate over such minerals as zircon, apatite, and sphene, etc. A study of the figures in the main table appended shows this clearly, and also the intermediate values given by hybrid rocks.

Certain noteworthy results arise from the present work which have a distinct bearing on *sedimentary petrography*. The first is the apparently complete absence of tourmaline from the rocks of the Channel Islands. Monazite has not been detected and this mineral remains characteristic (in Britain) of the Dartmoor and certain Scottish granites. Secondly, no source of rutile of any importance has been discovered, in fact what has been found is almost negligible. On the other hand sphene is most abundant and ubiquitous. These facts seem to point more than ever to the supposed authigenous production of rutile from sphene and ilmenite. Thirdly, the presence of well-rounded zircons in sediments need not necessarily imply long and possibly repeated abrasion, since the zircons may have been derived from a strongly gneissose rock, in which case they have probably been released in rounded condition. Work on the gneisses of Southern Guernsey shows that slight gneissic banding leaves the zircon unaffected, but that the rounding comes on with increase of intensity of the gneissic banding.

SUMMARY OF RESULTS.

The method attempted of correlation of plutonic masses by their accessory minerals is successful, and particularly so with the acid rocks. The results effected in the Channel Islands are as follows :—

1. Confirmation of the existence of granites of two ages in Jersey, and correlation of the Fort Regent and Gorey masses for the first time.
2. Correlation of the Cobo Granite of Guernsey with the "Older" Granite of Jersey (Gorey and Fort Regent).
3. Conclusive evidence to show that the Cobo Granite is the last stage of the Differentiation Series of North Guernsey, previously thought improbable.

4. The probable occurrence of both "Newer" and "Older" Granites in Alderney, making a Pre-Cambrian age for the "Newer" Granite highly probable.
5. The dissimilarity of the heavy residue of the "Newer" Granite to that of the Dartmoor Granite.
6. The similarity of the residue of the "Older" Granite with that of the Granite Gneiss of the Lizard and their suggested correlation.
7. The individuality of the gneisses of South Guernsey.
8. The occurrence in hybrid rocks of the mineral suites (particularly the zircons) of both rocks involved, consequently we have here a new method of demonstrating the hybrid nature of a rock.

Many rocks previously termed diorites in Jersey, Guernsey, and Alderney are shown petrographically not to be true diorites, some being gabbros, others hybrids.

The occurrence of acid-soused basic rocks in Jersey, Guernsey, and Alderney is pointed out, and their petrography described.

The occurrence of amphibolites in Roselle Bay, Alderney, is made known for the first time, and their petrography described.

In the course of the whole work sixty-three rock specimens have been crushed and passed through bromoform according to the method of procedure previously outlined, making an aggregate of about 15 lb. of rock crushed. From this crushed rock nearly four hundred slides of grains have been prepared, and of these about 90 per cent are nonmagnetic. In addition eighteen thin sections have been prepared.

I wish to thank Mr. A. E. Mourant, B.A., for some of the specimens of gneisses from southern Guernsey, and also Dr. G. H. Plymen for the specimens from Alderney. The rest of the material was collected by myself.

BIBLIOGRAPHY.

1. A. Brammall, *Mineralogical Magazine*, vol. xx, 1923, p. 40.
2. J. Parkinson, Geol. Mag., 1907, p. 74.
3. A. Brammall, *Proc. Geol. Assoc.*, vol. xxxvii, p. 251. *Mineralogical Mag.*, vol. xx, 1925, p. 319.
4. J. Parkinson, Geol. Mag., 1907.
5. J. Parkinson, op. cit.
6. J. Parkinson, op. cit.
7. T. G. Bonney and E. Hill, *Q.J.G.S.*, vol. lxviii, 1912, p. 36.
8. J. Parkinson, Geol. Mag., 1907, p. 77.
9. D. J. Farquharson, *Q.J.G.S.*, 1924, p. 374.
10. D. J. Farquharson, op. cit.
11. D. J. Farquharson, op. cit.
12. "Geology of Lizard and Meneage": *Mem. Geol. Surv.*
13. S. W. Wooldridge, Geol. Mag., Vol. LXII, 1925, p. 241.
14. S. W. Wooldridge, op. cit.
15. S. W. Wooldridge, op. cit.
16. E. Hill, *Q.J.G.S.*, vol. xlv, 1889, p. 380.
17. G. H. Plymen, Ph.D., *Thesis*, 1922, University of London Library.
18. G. H. Plymen, op. cit.

Eotriassic Ammonites from East Greenland.

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IN the present note it is intended to record a find of considerable importance to geologists and palaeogeographers, namely the discovery, last summer, by Mr. J. M. Wordie, St. John's College, Cambridge, of Lower Eotriassic ammonites at three localities on the south side of Gael Hamkes Bay, on the East Coast of Greenland, in 74° N. latitude. There are altogether ninety-five specimens, most of them well preserved, including various new forms, of which I hope to publish full descriptions elsewhere.

The first assemblage (No. 47, labelled "1,100 ft. altitude; south-south-west of Cape Stosch") includes thirty-three ammonites referable to:—

Ophiceras aff. *sakuntala* Diener.
,, aff. *evolutum* Frech.
,, spp. nov. i and ii.
,, spp. ind.
Koninckites, sp. n., aff. *kyokticus* (Krafft).

This is clearly an early Eotriassic fauna, later than the typical *Ophiceras* (*tibeticum*) beds of the Himalayas, but earlier than the lowest (*Gyronites*) beds of the Salt Range succession. There are also, preserved in the same greenish-grey, sandy, micaceous, limestone matrix, a number of specimens of *Pseudomonotis*, *Gervilleia*, etc., from the same locality.

From the second locality, No. 52, marked "600 ft. altitude, south-south-east of Cape Stosch", there are thirty-six ammonites apparently all specifically identical and belonging to

Proptychites sp. ind.

This genus is undoubtedly later than *Ophiceras*, and persists into the upper half of the Lower Trias, which includes the (true) *Meekoceras* Beds of California. It is thus probable that this *Proptychites* Bed is later than the *Ophiceras*-bearing bed 47 of Mr. Wordie's first section.

The third assemblage, No. 59, includes twenty-six ammonites from beds (with a dip of about 20° to the west) at 1,350–1,500 ft. altitude on the cliff section, 10 miles south-east of Cape Stosch. The ammonites represented are:—

Ophiceras aff. *sakuntala* Diener.
,, aff. *evolutum* Frech.
,, aff. *demissum* (Oppel).
,, spp. nov.
Vishnuites aff. *pralambha* Diener.
,, spp. nov. i and ii.
Koninckites sp. nov. aff. *kyokticus* (Krafft).

This is clearly of the same age as the first assemblage noted above, and likewise is associated with various *Pseudomonotis*, etc., in similar nodules.

The ammonite beds at the last locality are underlain by limestones and shales with brachiopods which Miss H. M. Wood considers to be Upper Carboniferous and not Permian. The beds above contain only badly preserved pelecypods that Mr. L. R. Cox thought to be possibly Triassic but not definitely identifiable.

Mr. Wordie adds that the Triassic beds are thrown into a wide syncline, striking approximately north to south, and that they are cut across, at about 1,600–2,000 ft. altitude, by Tertiary lavas and intrusive sheets of a thickness of about 1,000 ft.

The ammonites are important because they are all comparable to Himalayan forms. They belong to a fauna much earlier than the Lower Triassic assemblages so far known from Spitsbergen, or Northern Siberia, and are even older than the *Meekoceras* fauna of California. The only non-Himalayan locality that has yielded a similar assemblage is in Ussuri Bay (Sea of Japan). The distribution of seas and continents in Eotriassic times was thus probably much as represented by Diener,[1] who (in the writer's opinion, rightly) favours the permanence of continents. Arldt's [2] more recent attempt now requires considerable modification.

The writer is greatly indebted to Mr. Wordie for the opportunity of studying this interesting fauna; it enabled him to clear up several difficulties encountered in revising the classifications of Triassic ammonites for the forthcoming catalogue.

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[1] "Die Marinen Reiche der Triasperiode": *Denkschr. K. Akad. Wiss. Wien*, vol. xcii, 1916, pl. i.

[2] *Handbuch der Palæogeographie*, Leipzig, 1919, vol. i, p. 361.

REVIEWS.

THE GEOLOGY OF THE COUNTRY AROUND OXFORD. Second Edition. By J. PRINGLE, with contributions by K. S. SANDFORD and C. J. BAYZAND. Mem. Geol. Survey England. Explanation of special Oxford Sheet. pp. xiii + 191, 4 plates, and 12 text-figures, 1926. Price 4s.

DURING the eighteen years which have passed since the first edition of this memoir was written by T. I. Pocock, the need for a much finer zonal division in the Mesozoic, based on the nicer discrimination of genera and species and the establishment in the field of their range in time, has been generally accepted, and to a certain extent realized. As befits an official publication, the division into hemerae here adopted is conservative; the memoir not only presents a concise account of the Mesozoic (Inferior Oolite to Upper Greensand) of the Oxford district, but also indicates the zonal divisions which may be regarded as substantiated by field work, in the present state of knowledge.

The chapters (pp. 104–72) on the Pleistocene Deposits (Plateau Drift and River Gravels) are contributed by Dr. K. S. Sandford.

May we suggest that a companion special Cambridge Sheet and Memoir is not only much needed, but would prove a financial success?

A. G. B.

LATERIT, MATERIAL UND VERSUCH ERDGESCHICHTLICHER AUSWERTUNG. By HERMANN HARRASOWITZ. Fortsch. d. Geol. u. Pal., Band iv, Heft 14, pp. vi and 253–566, with 43 text-figures and 1 plate. Berlin: Gebrüder Borntraeger, 1926. Price 24 marks.

IT might be thought that a volume of over 300 pages devoted to laterite would fairly exhaust the subject, but that is far from being the case with the book under review. There is no indication that the author himself was ever in a laterite region, and his references to field observations in such regions are very scanty. The book is no guide to the work which has already been done upon the subject. It is an exposition of the author's ideas, based chiefly upon analyses of specimens collected by others, and for the most part he ignores the views of previous writers.

The first half of the volume is occupied by a discussion of the chemical changes which take place during the processes of kaolinization and lateritization, and the conditions under which they may occur. The most valuable part is a set of analyses of three series of specimens collected at Mangalore and Ettakot on the Malabar coast and at Mt. Lavinia on the west coast of Ceylon. In each case specimens were taken at different levels, ranging from the upper ferruginous crust of the laterite to the gneissic rock below. There are considerable differences in composition at the different levels and the author endeavours to show how these differences have been brought about. He concludes that a tropical climate is necessary, but neither continuous rain nor continuous drought will suffice. There must be an alternation of wet and dry periods.

The second half of the book is devoted to deposits of the past, in Europe and elsewhere, which the author believes to be of similar origin. They occur especially in the Carboniferous and the Tertiary, and are often associated with coal or lignite. The author tries to show that the climatic conditions favourable to the formation of coal and of laterite are similar. In the later part of the Tertiary period the evidence derived from plants with regard to climate requires a certain amount of manipulation to bring it into conformity with the author's views.

P. L.

KLEINE GEOLOGISCHE KARTE VON EUROPA. By F. BEYSCHLAG and W. SCHRIEL. Issued by the Prussian Geological Survey. Berlin: Gebrüder Borntraeger. Price 15 marks.

THE best small geological map of Europe which has appeared hitherto is that by Topley and Goodchild, dated 1888, which was published in the second volume of Prestwich's *Geology* but was also sold separately at a very low price. Naturally it is now out of date in several respects but still remains a very useful compilation. The map under review is dated 1925, but seems to have been actually published later. It is on the scale of 1 : 10,000,000, which is slightly smaller than that of Topley and Goodchild. It is not so minutely detailed in its execution, but it shows more subdivisions and covers a larger area. The geological colouring is extended to the borders so as to include Algeria, Asia Minor, etc., which are left blank in the other.

The colouring is clear and distinct, though perhaps a little gaudy. Most of the stratigraphical systems are divided into a lower and an upper series. The volcanic rocks are divided into three groups according to age and each group is subdivided into acid and basic. The limit of glaciation is shown, and in disturbed regions the greater overthrusts are indicated. The sea-floor is bathymetrically coloured in shades of blue.

There is, in addition, a transparent sheet which may be placed over the geological map and which is intended to show the main elements in the tectonic structure of Europe. The names applied to the different elements are those suggested by Professor Stille.

The map will prove extremely useful to the increasing number of geologists whose interests are not entirely parochial.

P. L.

IRON ORES—THE HAEMATITES OF THE FOREST OF DEAN AND SOUTH WALES. Special Reports on the Mineral Resources of Great Britain. *Mem. Geol. Survey*, vol. x, 2nd edition, pp. vii + 101, with 17 figures, 1927. Price 2*s*.

THE second edition of this memoir has been prepared by Mr. W. Lloyd, who has revised and brought up to date Dr. Sibly's earlier work. It has not been necessary to make many changes, as this industry has of late years naturally not made much progress, owing to the prevailing depression in the iron and steel trade which unfortunately seems likely to be more or less permanent. Mr. Lloyd has apparently visited most of the mines, if not all, and has successfully incorporated the results in the older text, as well as providing several new illustrations. The Forest of Dean is a district of considerable significance in the study of metasomatic iron-ore formation, throwing much light on the processes that have operated in other areas, and the revised memoir is well worth perusal by those interested in this subject. The discussion of the relation of dolomite-rock to this type of ore-formation is particularly clear and useful.

THE RADIOACTIVITY OF POTASSIUM AND ITS GEOLOGICAL SIGNIFICANCE. By A. HOLMES and R. W. LAWSON. *Phil. Mag.*, vol. ii, 1926, pp. 1218–33.

IN this paper the authors discuss the geological consequences following on their discovery that the potassium present in the igneous rocks gives rise to a total amount of radioactivity energy quite comparable in order of magnitude to that due to the disintegration of uranium and thorium. It follows that our ideas as to the thickness of the continents have to be revised in accord with the greater amount of heat thus shown to be generated. According to this estimate the continental crust must have an average thickness between 20 and 30 km., the lower estimate being preferable. The substratum below the continents and the ocean floor probably consist of eclogite with a density of 3·4–3·5. The downward distribution of rock-types is interpreted as granite–diorite–eclogite–dunite. Thus it will be seen that the thickness of the solid floor beneath our feet is gradually diminishing in the light of newer knowledge: in one publication Jeffreys has estimated it at only 15 kilometres. During the rigours of an English summer, like the present one, it is tantalizing to think what a lot of heat there is stored up only a few miles away.

REPORTS AND PROCEEDINGS.

Mineralogical Society.

14*th June*, 1927.

A. F. Hallimond: "On the atomic volume relations in certain isomorphous series."

The paper is based on accurate data made available by the researches of Dr. Tutton and other workers. For isomorphous salts of the eutropic elements K, Rb, Cs the differences Cs-K and Rb-K stand in constant ratio, and the same ratio holds good for the free metals though these are considerably larger than in the combined state; the constancy does not extend to the salts of NH_4 or Tl. A modified additive relation is indicated, the volumes of the metals when free and when combined being in the same ratio as the differences for the free metals and for the respective isomorphous series. In the same way volumes can be calculated for combined Na and Li from those from the free metals. Salts of Cl, Br, I exhibit a similar constancy in the ratio of their differences and this would appear to be a distinctive character of each "eutropic" group of elements. Volumes are calculated for combined Cl, Br, I. These and the other values for the acid radicles in the above series are in very close agreement with existing knowledge of the size of the atoms, a fact which affords strong confirmation of the validity of the method now proposed for computing the volume of the elements in the combined state.

Dr. P. K. Ghosh: "Petrology of the Bodmin Moor granite (eastern part), Cornwall."

Three types of granite are mapped and described in detail: (1) an earlier coarse-grained "normal granite", followed by (2) a coarse-grained granite of Godaver type, and (3) a fine-grained granite. Various minor intrusions connected with these are described and also their altered facies. Several types of hornfelsed inclusions of sedimentary rocks are distinguished. Eight detailed chemical analyses are given of the rocks.

Professor P. G. H. Boswell: "On the distribution of purple zircon in British sedimentary rocks."

The properties and behaviour under radio-active treatment of purple zircon from sedimentary rocks are described. The distribution of the mineral in British sedimentary rocks is considered in some detail, for it occurs at practically every horizon. In the Carboniferous, Permian, Triassic, and Aptian rocks, it is especially abundant, and is there associated with numerous other minerals apparently freshly derived from crystalline metamorphic rocks.

Dr. J. Drugman: "On β-quartz twins from Cornwall."

β-quartz seems to be sufficiently differentiated from α- or low-temperature quartz for the two to be treated quite apart from each other. This is specially the case with the twin-laws observed in these. In β-quartz, twinning with inclined axes is a very common occurrence indeed and examples are very abundant in the Cornish localities visited by the writer, namely Belowda Beacon, a china-clay pit near Belowda Beacon and Wheal Coates. Besides twinning on $(10\bar{1}1)$, Estérel twinning, and twinning on $(11\bar{2}2)$ three new laws were found by the author, namely twinning on $(30\bar{3}2)$, confirmed by a good Estérel specimen; twinning on $(20\bar{2}1)$ (and perhaps on the Zinnwald law), and lastly twinning on $(21\bar{3}2)$, also confirmed by an Estérel specimen. This latter is, however, probably of extremely rare occurrence.

E. V. Holt and Dr. H. F. Harwood: "The separation of manganese in rock analysis."

In carrying out the exact analysis of rocks the whole of the manganese they contain can be completely precipitated with the alumina and ferric oxide by employing the following procedure: The solution after removal of silica is diluted to 400 cc., heated to boiling after the addition of ammonium chloride, and ammonia added to alkalinity. Bromine water is then run in slowly from a tap funnel whose stem is drawn out to a fine jet, small additional quantities of ammonia being simultaneously added to keep the solution alkaline. When the addition of the bromine is complete the liquid is boiled for one minute and then filtered. The precipitate is redissolved and the precipitation repeated; in the combined filtrates lime and magnesia are determined by the usual methods. The results are perfectly satisfactory up to a limit of 50 milligrams MnO; when more than that quantity is present some lime and magnesia are liable to be carried down with the alumina precipitate, but such a case will practically never occur in rock analysis.

Dr. L. J. Spencer: "Corundum twins from the Transvaal."

Large twinned crystals of corundum, up to 6 inches across but only about an eighth of an inch thick, are abundant in plumasite rock near Bandolier Kop, Northern Transvaal. The twin-plane is a face of the primary rhombohedron and the twinned crystals have a form resembling arrow-heads.